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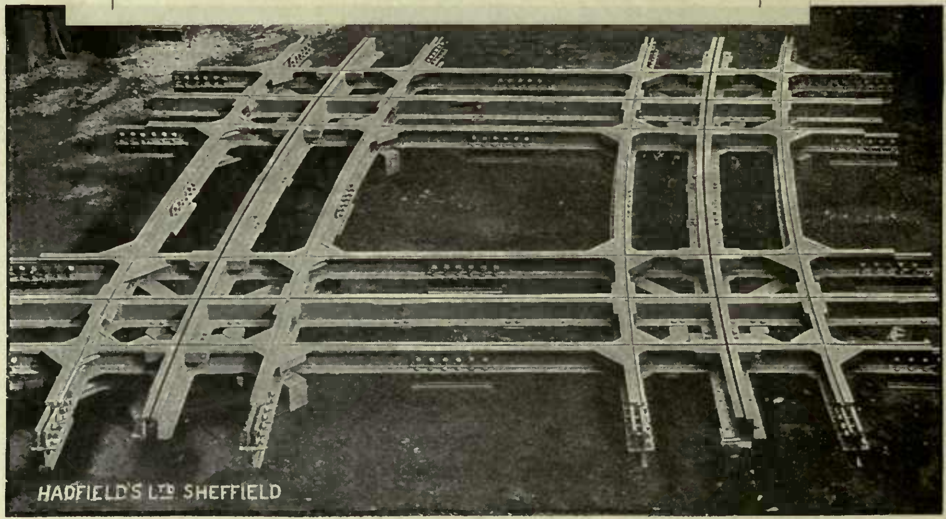

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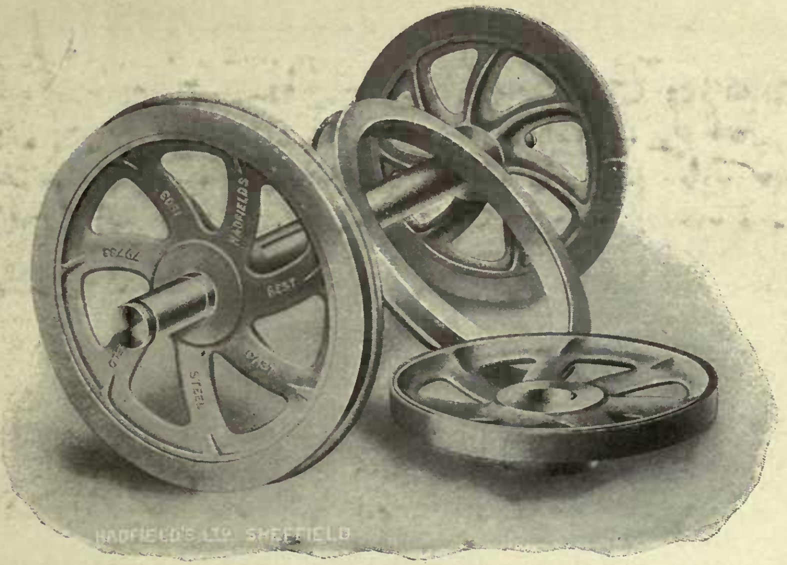

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No. 6.

PERMANENT WAY

. . FOR . .

TRAMWAYS & STREET RAILWAYS

. . BY . .

THOMAS ARNALL,

Assoc. R.C.Sc., Dublin ; Assoc. M. Inst. C.E.

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PREFACE.

THE contents of this Volume are based upon a series of articles published in the *Railway Engineer* and which have been revised and supplemented as occasion seemed to require.

Tramway construction is not a simple matter, and few engineering structures are less permanent than the Permanent Way of a tramway, and, in spite of long experience, many factors essential to the stability of the work are but imperfectly understood. An attempt, guided by 20 years' experience of Tramway Permanent Way under Mechanical Traction, has therefore been made to emphasize certain mechanical and scientific principles which are frequently lost sight of.

Parliamentary questions and the control exercised by the Board of Trade under the Tramways and the Light Railways Acts have been dealt with rather fully, and copious extracts from the Acts and typical Provisional Orders so far as they deal with engineering (as apart from rolling stock questions) have been given in the appendices.

The Author is indebted to Messrs. DICK, KERR & Co., Ltd, J. G. WHITE & Co., Ltd., and Mr. A. N. CONNETT for assistance in the matter of Conduit Tramways. Thanks are also due to Messrs. HADFIELDS' and others referred to in the text for illustrations and particulars of numerous details of Permanent Way, Tools and appliances. His thanks are also especially due to Mr. JOHN PRICE, M.Inst.C.E., City Engineer and Surveyor to the Corporation of Birmingham, for kindly reading through the proofs and making numerous and valuable suggestions.

Birmingham, 1905.

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PERMANENT WAY FOR TRAMWAYS AND STREET RAILWAYS.

CHAPTER I.

Rules as to Construction and Maintenance.

When a tramway is laid in a public road, new conditions arise as to the repairs and maintenance of that road: in some respects these are quite apart from the actual operations necessary in carrying out the works. These extraneous matters may be of a legal, rather than an engineering, character, but to enable an engineer to carry out his duties in an intelligent manner, it is often essential for him to possess some notion of what the legal position really is.

In the first place, it is well established that the local authority, or other body having charge of the roads, is not responsible for the effects of an accident caused by the defective state of a road which it is part of their duty to maintain, when that road had been made or repaired in a proper manner, and the defect in question is a natural consequence of ordinary wear and tear. The parties dissatisfied with the condition of a road can summon those charged with the duty of repairing it before the magistrates, and obtain an order for its repair: if they do not avail themselves of this remedy they cannot afterwards make a claim for the results of the want of repair. If, however, the local authority, or other parties having proper legal powers, place something in the road, such as valve boxes on gas or water mains, sewer ventilators, or tram rails, or other structures, they have to take proper care of them, and see that the effects of wear and tear upon the road does not result in these extraneous matters becoming an obstruction and source of danger to the general public having a right to the use of the road. If they fail in this, they must take the consequences and become liable for any accident that may occur.

Formerly tram rails could only be placed in a road by definite Parliamentary sanction. Under the Light Railways Act a tramway may now be constructed by authority of the Board of Trade without the formality of an Act of Parliament, but the requirements of the Board do not differ from what they would be in the case of a regular tramway. The Board are practically masters of the situation in any case, and the result, so far as repairs and maintenance go, is the same whether the tramway be authorised by a special Act, by a Provisional Order under the Tramways Act, 1876,* or by one under the Light Railways Act, 1896.† The Board of Trade

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* See Appendix I. † See Appendix IV.

(defined as "the Lords of the Committee of Her Majesty's Privy Council appointed for Trade and Foreign Plantations") were given certain powers in connection with railways under the Railway Clauses Act, 1845. The tramways laid prior to 1870 had to be dealt with as railways; the 1870 Act introduced a new form of procedure for them, and extended the powers of the Board of Trade. In effect the Board controls the tramway so far as regards construction and maintenance: the section of rails and details of construction are not prescribed, but they are to be subject to approval, and before the construction of a tramway is commenced, the Board has to be furnished with:—

1. A drawing (in duplicate) consisting of full sized section of rail, plan and elevation of same extending about 9 ins. on each side of joint, and showing how the joint is to be secured, and the electrical bonding.

There should be a statement on this drawing of the material, weight and length of fishplates; depth and width of groove; and whether tramway is to be worked by mechanical power.

2. A drawing (in duplicate) on a scale of 2 ins. to a foot, consisting of plan, cross section and longitudinal section of the permanent way and substructure of the tramway, and showing the mode of fixing the rails and chairs (if any) and the gauge ties (if any).

This drawing should bear a statement of the nature of the pavement between the rails, and for a distance of 18 ins. outside them.

Also, on a scale of one inch to a foot, a plan of the points proposed at single line passing places and junctions.

The Provisional Order‡ further stipulates that

> "the promoters shall not commence the construction, laying down, maintenance and renewal of the tramways . . . until such plan and statement have been approved by the Board of Trade; and after such approval, the works shall be executed in accordance in all respects with such plan and statement."

It is curious that the Act of 1870 makes no direct provision for the maintenance of the tramway, except that (Sec. 25) it

> "shall be laid and maintained in such a manner, that the uppermost surface of the rail shall be on a level with the surface of the road."

The Provisional Order always extends this, and stipulates that the

> "promoters shall at all times maintain, and keep in good condition and repair, and so as not to be a danger or annoyance to ordinary traffic, the rails of which any of the tramways for the time being consist, and the sub-structure upon which the same rest,"

and furthermore, if

> "in any case it is represented in writing to the Board of Trade, by the road authority of any district in which the tramways are situate, or by twenty inhabitant ratepayers of such district, that the promoters have made any such default,"

the Board of Trade may direct an enquiry, and if they certify that the default mentioned in such representation is proved to the satisfaction of the Board,

"the promoters shall make good such default in the manner, and within

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‡ See Appendix III.

> the time specified in such certificate, and if they fail to do so, shall be subject to such penalty or penalties in respect of such failure as is, or hereinbefore imposed in respect of offences."

This is a ponderous method of getting the necessary work done, and is in great contrast with the procedure specified in case of defects in that part of the roadway which the promoters have to maintain.

This is as follows :—

Sec. 28 of the Act of 1870, provides that :

> " The promoters shall, at their own expense, at all times maintain and keep in good condition and repair, with such materials and in such manner as the road authority shall direct, and to their satisfaction, so much of any road whereon any tramway belonging to them is laid, as lies between the rails of the tramway and (where two tramways are laid by the same promoters in any road at the distance of not more than four feet from each other) the portion of road between the tramways, and in every case so much of the road as extends 18 inches beyond the rails of and on each side of any such tramway."

Further on in the same section it is stipulated :

> " Provided always, that if the promoters fail to comply with the provisions of this Section, the road authority, if they think fit, may themselves at any time, after seven days' notice to the promoters, open and break up the road, and do the work necessary for the repair and maintenance . . . to the extent in this Section above mentioned, and the expense incurred by the road authority in so doing shall be repaid to them by the promoters."

The Provisional Order generally stiffens these requirements as follows :—

> " If at any time any part of any road in any district in which the tramways are laid, which part is by the Tramways Act, 1870, or by this Order, required to be maintained and kept in good condition and repair by the promoters, shall, in the judgment of the road authority of such district, be not maintained and kept in good condition and repair, then it shall be lawful for such road authority to repair and mend the same, and to recover the costs incurred by them in so doing from the promoters by all and the same means as any simple contract debt of like amount may be recovered; and it shall be lawful for such road authority to stop the traffic along any part of the tramways where any such part of any road is, in the judgment of such road authority, out of repair, until such part of such road shall have been put into good condition and repair to the satisfaction of such road authority."

These quotations show that there is a marked difference between the tramway and the road in which it is laid. In one case the local authority has the matter in their own hands; in the other, appeal must be made to the Board of Trade. It is not very clear what is to be done when tramway and roadway in themselves are both in satisfactory condition, but one not level with the other. This case is generally referred to as rails " too high " or " too low," as the case may be; but as a matter of fact a rail generally remains at the level at which it was originally fixed, or changes but an inappreciable amount. The adjacent paving, however, is rarely in this stable condition; when the bedding is disintegrated and washed out through the open joints, the pavement sinks; when the joints are tight, there is no escape for the water and detritus forced under the pavement by a loose rail, and it consequently rises. Probably the correct technical way of dealing with these cases is to consider them as defects in the roadway; the pavement has not been maintained at its proper level, and it is therefore a matter the local authority can deal with.

The effects of wear and tear upon the "tramway" are not usually of such a nature as to greatly affect the safety or convenience of the general public. Points and other castings must be renewed from time to time, because in their worn condition they are not right for the tramway traffic. The rails sometimes have to be renewed when the worn down tread leaves the lip or guard, projecting so as to be a source of danger to ordinary vehicles. This can be avoided to a great extent, and the life of the rail considerably extended, by starting with that lip as far below the level of the tread as the Board of Trade will allow. The places where the effects of wear and tear are most severely felt are at the joints; if these are not well designed, the rails may have to be renewed long before they are otherwise worn out. It may be economy to change the rails, so as to get rid of the expense of lifting and replacing the pavement round these bad joints, and to save also their destructive effect upon the rolling stock.

*The Light Railways Act, 1896**.—

This Act introduces some entirely new features into the conditions of tramway construction : so long as it remains in force such work is not necessarily governed by the provisions of the Tramways Act, 1870. The Act was to remain in force five years only, but it has been kept alive by the "Expiring Laws Continuance Act, 1901" and subsequently, and there is no doubt that the Act as it stands, or some modification of it, will become a permanent enactment. In considering its provisions the exact terms of the Act must be read in the light of the interpretations that have been put upon them. Apart from these interpretations, a reader of the Act would say that its obvious intention was to facilitate the construction of railways only, and that it had nothing whatever to do with tramways in a public street or road. There is continual reference to Railways and Railway Companies throughout the Act, but none to tramways; provisions are made for making junctions with railways, but none for making junctions with tramways : subject to certain exceptions specified "the general enactments relating to railways shall apply to a Light Railway "under this Act in like manner as they apply to any other Railway" (Sec. 12); but there is no mention of the general law applying to tramways. There is nothing whatever in the Act that would lead one to suppose that it could have any bearing upon street tramways, and yet, during the discussion on the Bill in the House of Lords, Lord Morley said, "It includes not merely all tramways, but any railway "which the Board of Trade thinks may justly be brought within its scope. It "certainly includes tramways in towns, and it might include large trunk lines "throughout the country."

The Board of Trade have adopted this liberal interpretation in administering the Act : it has enabled them to turn over a new leaf, and so long as the promoters call their scheme "a light railway," to consider it upon its merits and with due regard to the circumstances of the case, without being hampered too much by Acts, rules, and precedents. It provides a new form of procedure, bearing about the same relation to the Tramways Act, 1870, as that Act does to the law previously in force. That Act empowered the Board of Trade to enquire into and settle the details of a proposed Tramway, and to make a Provisional Order authorising its construction and working : this Order, however, was of no effect until it had been confirmed by Parliament. The Light Railways Act creates a new Commission of three members to be appointed by the President of the Board of Trade. These Commissioners have to enquire into and settle details of any proposed Light Railway, and make a Provisional Order thereon. This Order is of no effect until it has been confirmed by the Board of Trade. It then becomes law without reference to Parliament, unless the Board is of opinion that such reference is advisable because of certain circumstances connected with the case.

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* See Appendix IV.

The wide interpretation put upon the Act causes the works authorised under it to be of two quite different kinds*, and the form of the Order varies accordingly. In the one case the Light Railway approximates in type and construction to an ordinary Railway, with ungrooved rails on transverse sleepers, and carried across the open country, or along the waste on the road side. In the other class the type of construction may be identical in all respects with a street tramway, and differing from a line laid under the Tramway Act perhaps only in the conditions of the company's tenure.

Under an order of the railway type there is little to distinguish the works from an ordinary railway, except the evident economical methods of construction and the general absence of many things usually considered essential, such as fences, level crossings with protecting gates or signal boxes, &c. The Act makes it the duty of the Commissioners to facilitate as far as possible the construction of light railways, and hence many of the expensive adjuncts and precautions taken to ensure public safety have to be omitted. It is quite possible that the experience so gained may be of service on other than light railways when the Board allow the circumstances of each case to exercise an influence upon their rules and regulations.

When the Light Railway Order is of the tramway type, great variations from standard tramway construction may be introduced; and there are also notable variations in other matters. There is no mention, for instance, of the " frontager," *i.e.*, a person who is the owner or occupier of premises abutting upon a part of the road where for a distance of 30 ft. or upwards it is proposed to lay a tramway so that the distance between the outside of the footpath and the nearest rail will be less than 9 ft. 6 ins. If one third of such frontagers object, that part of a tramway is blocked in an Order under the Tramway Act. Under the Light Railway Act the frontager must lodge an objection with the Commissioners, who have to take all such objections into consideration and report to the Board of Trade the manner in which they have been dealt with. If the objections are not withdrawn the Board have to consider them, and give those by whom they are made an opportunity of being heard. If the Board decide that the objections should be upheld they will not confirm the Order. It is evident that no arbitrary " objection " to a rail being laid in any given position in the road is likely to be of any avail when weighed against the needs of the general public.

A Provisional Order under the Tramway Act cannot confer the power of compulsory purchase of land required for widening the roads or for other purposes of the undertaking. A Light Railway Order can give this power, and it is one of the most useful innovations introduced by the Light Railways Act.

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* See Appendices VI. and VII.

Other notable departures from tramway precedents affect the local authority. Their consent is not necessary to a Light Railway Order as it is to a tramway; and in the matter of compulsory purchase, their powers generally are made to arise only after a longer interval than the 21 years fixed by the Tramway Act. The price to be paid then is not merely "structural" value, but may be the value of the undertaking as a going concern, but without any allowance for compulsory purchase.

The clause in the Model Order regulating the breaking up of the roads for the purpose of constructing the railway is practically the same as Section 26 of the Act of 1870, and in addition thereto, it is provided that previous to the work being done a plan shall be laid before the Board of Trade (and the road authority also if work is done by a company), showing the proposed mode of constructing the railway, and a statement of the materials intended to be used. The works are not to be commenced until such plan, &c., have been approved by the Board, and all such works shall be constructed in accordance with such approved plan and statement. The provisions for the completion of works and reinstatement of the road are the same as in the corresponding section of the Act of 1870.

The materials of macadam, paving, &c., excavated in carrying out the work, may, as on a tramway, be used in reinstating the road, and surplus materials handed over to the surveyor.

The clause as to repair of the road differs notably from the corresponding clause in the Tramway Act. It is there provided (Section 28) that the promoters shall at all times "keep in good condition and repair, and in such manner as the road "authority shall direct, and to their satisfaction, so much of the road . . . ." as extends to 18 inches outside the rails. " . . . . if the promoters fail to "comply with the provisions of this section, the road authority, if they think fit, "may themselves at any time . . . . open and break up the road and do the "work necessary for repair of the road to the extent above-mentioned, and the "expenses incurred in so doing shall be repaid to them by the Promoters." This is characteristic of the Tramways Act; while it makes the Board of Trade masters of the tramway, it leaves all questions touching the road in the hands of the road authority. In a Light Railway Order, the Board take up very much the same position with regard to the road, as they have always assumed with regard to the tramway, or railway. The Railway Order directs that the company "shall at all "times repair . . . . and keep in good condition, with such materials and "in such manner as the Company and the road authority may agree, or as, in case "of difference between them, may be determined by the Board of Trade, so much of "any road . . . . &c.," and to a width of 18 inches outside the rails.

"The rails of the railways shall be such grooved or other rails as the Board "of Trade may approve. They shall be laid and maintained in such manner that "the uppermost surface thereof shall be on a level with the surface of the road." A proviso follows to the effect that if the road authority alters the level of the road, the company shall alter their rails so that the uppermost surface shall be level with the surface of the road as altered. This is a similar clause to the one inserted in Tramway Orders, and it has been the cause of several disputes between the road authority and the tramway company, as to whether the company has to be at the expense of altering the level of their rails only, or whether they must be at the expense of altering the level of the portion of road repaired by them. No authoritative decision upon this point appears to have been given in connection with a tramway, but the issue was raised in connection with the South Shields Light Railway Order, when the Tynemouth Corporation asked for a clause requiring the company to alter the level of their portion of the road as well as the level of the rails in the event of the road being altered as indicated. In the Order as finally settled it was provided that in the event of any alteration of level of the road by the road authority the company should be required to alter the level of their rails only.

A sett paving, either of granite or of wood blocks, is taken as an essential requirement on a tramway. This matter used to be left for settlement between the company and the road authority, but lately the Board of Trade have required, when the drawings showing proposed mode of construction are submitted to them for approval, a statement upon such drawings defining the nature of the paving to be adopted between the rails and for 18 inches outside them. Occasionally a statement of the paving to be used has been inserted in the Tramway Order, generally in protecting clauses as the results of bargainings between the company and the road authority, and when the difference between them has been a matter of granite *v.* wood, or hard wood *v.* soft wood. In a Light Railway case, however, the road authority is in a less commanding position, and in settling differences of opinion the leading idea with the Board of Trade is evidently the duty laid upon them by the Act of doing what they can to facilitate the construction of the railway. Where it passes through a purely urban district the Board will require the whole area paved, which has to be maintained by the company. The circumstances, however, are frequently such as to justify the Board in requiring that the paving shall extend to one sett only alongside the rails of an average width of 6 ins. to 8 ins.; the other part of the road being maintained in macadam, rolled and levelled to the required surface. When the distance between rail and kerb becomes less than 9 ft. 6 ins. on a tramway, the company is nearly always under the obligation to pave and maintain the whole of that surface; on a light railway their liability extends only to the usual width of 18 ins. outside the rails, even when the line is laid to a narrow gauge, or when the 18 ins. paved margin comes within a few inches of the kerb. In some cases the setts alongside the rails have been dispensed with, the line laid with ungrooved rails, and the road completed in macadam, the groove being formed therein by the wheel flanges.

As to the necessary permanent way adjuncts when the railway is to be worked by electric power, the Model Order provides as follows :—

"Subject to the provisions of this Order . . . . may lay down, erect and "maintain on, in, under or over any road, or the footpath of any road, such posts, "conductors, wires, tubes, mains, plates, boxes, and apparatus as may be necessary

" or convenient either for the working of any of the railways, or for forming con-" nections with any generating station." Under a tramway this would be impossible, because in the Tramway Act the word " road " is defined to mean the " the carriage way of any road," and the Board of Trade have therefore no power to sanction any interference with footways. They equally have no power to prevent it, provided the road authority consents; and hence some tramways have been adapted to electric traction in this way because it has not been worth while for anyone to question the extent of the exact rights and powers of the parties concerned. The Light Railways Act imposes no such limits, and electric traction may be legally adapted without the necessity of having to obstruct the carriage way with posts, &c.; they may be placed on the other side of the kerbstone. All posts, standards, brackets, and other attachments for the overhead work must be of such design and construction as the road authority and the Board of Trade may approve, with, of course, power to the Board to decide in the case of difference of opinion. The local authority may also use the posts, &c., for the support of any electric wires or lamps, or any gas lamps used for lighting the streets; but power to use them for carrying oil lamps and for other purposes has been repeatedly refused.

It is evident that the Light Railwavs Act offers peculiar advantages to the promoters of a tramway scheme. Under a Provisional Order they are restricted by the Tramways Act, and almost equally so when they seek powers by a private Bill. More than half the light railways that have been promoted or authorised since the Act came into force have been street or road tramways in all essential particulars; but their construction *as* tramways would have been quite impossible in many cases owing to the expense involved in carrying out the conditions automatically imposed by the older Acts and precedents.

* * *

CHAPTER II.

CONCRETE FOUNDATIONS.

It may be open to question whether the concrete and paving really form part of the permanent way of a tramway, except so much of the former as is necessary for the stability of the rails. If the paving be not part of the tramway proper, in any case it is a part of the company's undertaking to maintain (to the satisfaction of the local authority) a certain area of the road on which the tramway is laid. The concrete foundation and paving are necessary to satisfy the local authorities in this respect, and these matters thus become parts of the constructive works for which the tramway engineer is responsible.

As a rule a concrete foundation is required on a tramway for the paving only; the rails would be better supported on timber sleepers, the less rigid road thus formed giving much smoother running and causing less wear and tear to the rolling stock. Unfortunately a satisfactory pavement cannot be well maintained except on a rigid and continuous foundation, and concrete is the only substance practically available for constructing such a foundation.

The use of Portland cement as the cementing medium in making concrete is now fairly universal. Good concrete can be made with lime, lias, hydraulic or otherwise, but it sets too slowly for street work, and is, therefore, not suitable for tramways.

Portland Cement.—

The essentials of a good cement are that it shall be finely ground; shall attain certain specified tensile strengths in given times; shall be free from adulteration, and shall be cool and ready for use. It is sometimes further specified that it shall weigh 112 lbs. per imperial bushel, and shall not contain more than a given proportion of magnesia. This last is a chemical matter which is chiefly of importance in work exposed to the action of sea-water, and is not of much consequence in tramway construction; it may, therefore, be safely left in the hands of a reliable cement manufacturer. The weight per bushel is a test altogether misleading to the user, and is, therefore, worse than useless. Cement is made by grinding up a clinker having a specific gravity of a little over 3. A weight of 112 lbs. per imperial striked bushel corresponds to a specific gravity of about 1·4, so that the measure which has been "filled from an inclined board" contains less than half of solid cementing matter, because a quantity of air has been entangled in the finely ground powder. A coarser powder would carry down less air, and would, therefore, weigh more per bushel, and when it was found that this heavier powder made a stronger bricquet in the usual tensile test, it seemed to follow that the quality of the cement was in some way proportional to the weight of the powder. Further investigation showed that this is only true when the cement is used neat, and the heavier particles of the coarsely ground cement which go to increase its weight are acting very much in the same way as so much sand, and are almost devoid of any cementing quality. The test is furthermore misleading, inasmuch as it is found that the weight decreases with the age of the cement, and to require a heavy weight per bushel is tantamount to asking for a coarsely ground cement fresh from the mills, which may be, therefore, lacking in the two quite essential properties of coolness and fineness of grain.

Fineness of Cement.—

This is one of the most important qualities in a cement. It is as though its whole virtue as a cementing material depended upon the area of surface that can be covered by the powder, and this is obviously inversely proportionate to the size of its particles. In recent years cement has greatly improved in this respect, and it is easily obtained ground so fine as to leave a residue of not more than 2 or 3 per cent. on a sieve of 5,800 meshes to the inch. When a sieve is specified merely by stating the number of meshes per square inch, the size of the holes, and therefore the fineness of the cement which has to pass through, it is left an open question, unless the size of the wire be also given. Mr. Butler* gives the following as the usual proportion :—

No. of Sieve.	Size of Wire S.W.G.	Equivalent in inches.	No. of Meshes per square inch.
25	29	·0136	625
30	31	·0116	900
40	34	·0092	1,600
50	35	·0084	2,500
70	38	·0060	4,900
76	39	·0052	5,776
80	39	·0052	6,400
100	41	·0044	10,000
120	43	·0036	14,400
180	45	·0028	32,400
200	46	·0024	40,000

The diameter of the wire does not bear any definite relation to the size of the mesh, being about equal to half the distance from centre to centre of the wires in the case of the two finest sieves; from ·40 to ·45 that distance in the sieves; from 50 to 120 wires to the inch, and about one third the distance for the two coarsest sieves. The very fine sieves are rather delicate and require careful handling.

The residue remaining on even the fine sieves has very little value as a cementing material. Made up neat into a bricquet it will show some small tensile strength, provided it be left in soak for a sufficient time; when mixed with sand its cementing power is almost nil.

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* "Portland Cement," its uses, &c., by D. B. Butler—London : Spon.

The limit of a practical sieve is not far from 200 wires to the inch, and the most active particles of a good cement are much finer than a passage through such a sieve would necessarily imply.

The "Flourometer" (Goreham's patent) affords a new method of ascertaining the proportion of flour in the material. A current of air is blown by mechanical means through a given weight of cement until all the extremely fine particles constituting the flour are removed, and the proportion then ascertained by weighing the residue. Cement which has been passed as satisfactory by testing with the 5,800 mesh sieve, gives about 40 per cent. of flour when tested in this apparatus. Under the microscope the great bulk of the flour appears to be made up of particles about 1,000 of an inch, and less in diameter; a good proportion is only about 1-10 of this size, and still finer particles are only just visible under a power of 400 diameters. The extended use of some such apparatus cannot but have a beneficial effect in directing attention to the really active part of the cement. At present the buyer is paying a low price for a mixture of flour and something which is little better than fine sand; this coarsely ground stuff is solely responsible for the blowing or unsoundness of the cement, and its removal is to be desired for this reason alone.

Tensile Strength of Cement.—

Good cement tested neat should develop a strength of 400 lbs. in 7 days, and 500 lbs. in 28 days. When mixed with "normal" sand in the proportion of 1 to 3, the strength of the bricquet should be at least 125 lbs. per square inch in 7 days, and 175 lbs. in 28 days. The test with sand is really a test of the fineness of grinding, and if it were not for the uncertainty introduced by the quality of the sand itself, there is no reason why the test of the neat cement should be of any particular interest to the user. A test which places the cement under conditions approximately similar to those in which it will be used, is of more value for practical purposes than one carried out under abnormal conditions; the only objection to the sand test is the difficulty of getting perfect uniformity in the sand. The normal or standard used for testing purposes is the pure silica sand from Leighton-Buzzard, washed and sifted so as to pass through a sieve of 20 meshes, and to be retained on one of 30 meshes to the inch. A test with the sand actually used in the work would give an idea of the result of using the cement under examination, but if the result were not perfectly satisfactory, it would leave in doubt the question as to whether the fault lay with the cement or the materials that had been mixed with it.

Soundness or Freedom from Uncombined Lime.—

This is best ascertained by making up a small pat of the cement, and placing it in water as soon as it is properly set; the cement may be considered fit for use if the surface of the pat develops no cracks in 4 or 5 days. This process may be accelerated by artificial heat, but in a general way a result got at in a hurry is open to suspicion. The effects of a hot bath are unduly severe on the cement; it may fail under the artificial conditions, and yet be perfectly sound and suitable for the purpose for which it is required. The necessity for accelerated tests is best avoided by not allowing any of the cement to be used until it has been delivered on the ground, or to some depôt in time for the proper examination, before it is required for use in the work. The proportion of cement and aggregate in different samples of very good cement differ very widely, but generally it may be taken that one part of cement to seven of the other materials will give a satisfactory mixture. Equally good concrete may be made with a very much lower proportion of cement than this, *provided* that the care and labour in mixing and laying the concrete be increased in proportion to the reduction made in the cement. For equally good results it is doubtful if the value of the cement saved in this way is equal to the cost of the extra labour involved in mixing and placing the concrete.

The object to be attained is the production of a solid compact mass without sensible voids; empty space cannot be filled by the aggregation of irregular lumps of hard material so long as they are of uniform size; if the lumps vary very much in size the object may be approximately attained. For example, an aggregation of uniform spherical bodies will only fill about 75 per cent. of the total space; that is, the volume of void spaces amounts to about 25 per cent. of the whole—this proportion is quite independent of the size of the bodies so long as they are spherical and of uniform size; if the spheres are not of uniform size, the proportion of void may be made as small as you please by properly varying the sizes. With irregular lumps of a roughly uniform size thrown together loosely, the proportion of void space will generally be found to average from 45 to 50 per cent. of the whole.

This is the shape of the material which is to be used for ballast in the concrete; what it is composed of will have to depend largely upon circumstances. The promoters of a tramway are nearly always entitled to use such of the excavated materials as may be suitable in reinstating the road, and macadam broken up is usually excellent material as a basis for concrete; that is to say, it is an excellent material provided it is clean, and unless it be screened and riddled in a perfectly dry state this condition will not be fulfilled, and the quality of the concrete will suffer in consequence; in any case all that passes through a ½-in. riddle must be rejected and the necessary fine stuff be supplied by new materials. In the absence of old macadam, local conditions will determine what is best to be got under the circumstances; broken stone, bricks, or slag or such like angular materials should always have the preference over rounded gravel, and the largest pieces of this ballast should be capable of being passed in any direction through a 2½-in. ring. This is the maximum, and the size will vary down to what would be stopped on a ½-in. riddle.

The quality of the small stuff to be mixed with this rough ballast is probably of greater importance than that of the ballast itself, inasmuch as it has to be depended upon to consolidate the whole mass; it should be clean and sharp (that is, not rounded particles), not necessarily of uniform size, and must be free from clay or loam; if freedom from clayey matters cannot be obtained in any other way the material should be washed; coarse sand, crushed blast-furnace slag, the fine stuff from a stone breaking machine from which the dust has been excluded, may be mentioned as good material for the purpose. It is usual to specify the quantity of this fine stuff, such as 2 parts of sand to 5 parts of broken stone, and specifications are often met with in which the proportions have to be expressed by fractions. When the material that is going to be used is well known beforehand, such niceties of expression may be justifiable, but in the absence of such knowledge it can only be stated in general terms that there must be sufficient of this fine stuff to at least fill the voids in the mass of broken ballast, and it is well to provide for 10 to 15 per cent. in excess of this quantity; this minimum quantity is best determined from the materials actually used in the work by filling a bucket with the broken ballast and then seeing how much water has to be laded out of another similar bucket to fill the interstices, proper allowance, of course, being made for any absorption by materials of a porous nature. This will give a very fair notion of the right proportion of sand or other fine stuff to be used with that particular quality of ballast, when the mixture has simply to be turned over a few times and shovelled into place: if it is going to be punned or rammed until it is solid, the proportion of fine stuff may be reduced with advantage, as more of it than is really necessary to properly flush up the voids will be, in effect, a waste of cement.

The cement is practically all required to form with the sand a mortar in which the larger pieces of ballast are imbedded; and it will be found that the volume of the mortar produced is less than the united bulk of its two constituents by about 25 to 33 per cent., according to the relative proportions of the cement and sand in the mixture. When the proportions of aggregate sand and cement have been ascertained they should be adhered to until there is an adequate reason for varying them; this often presents itself in a variation in the type of ballast, &c., available for the work. The only way to obtain correct proportions is to have all the materials measured in proper sized gauge boxes and have all the mixing done on moveable wooden platforms.

Generally, it is convenient to fill a cube yard box with rough ballast, level the top, and place a smaller box for the sand upon it and fill this also, and then fill a still smaller box containing the cement. When these boxes are lifted off, the heap should be completely turned over twice in a dry state. During the third turning water should be added *through a rose*. After a fourth turning on the platform the mixture will be ready for shovelling into place, and this process will constitute a fifth turning, and will be sufficient to incorporate the mixture. The amount of water to be added must be sufficient to thoroughly wet the whole, an excess will tend to wash away the cement, a deficiency will result in an open porous concrete; the exact amount must be left to those in charge of the work, as it will to a great extent depend upon the materials being used.

Some engineers require the concrete to be laid in place and time allowed for it to become properly set before the rails, &c., are laid upon it. In cases where the bottom is particularly bad this may be necessary, but in ordinary cases it is far better to excavate the ground to the full depth and then set the rails to their proper lines and finished levels, supporting them every 8 or 10 ft. on a couple of bricks; by this means a far better top can be given to the road than when the levels are hampered by an existing bed of concrete. The mixing may then be carried out on wooden platforms supported on skids clear of the rails; on no account should these boards be carried on the rails, as if they are forced out of place their re-adjustment after the concrete is laid would be a troublesome matter. The rails are far more likely to get a continuous bearing by packing a mass of concrete of substantial and uniform thickness, than when they have to be carried upon a thin layer rammed under them whenever there is supposed to be room for it.

*British Standard Specification.**—

Since the above was put into type the Engineering Standards Committee have issued their Standard Specification for Portland Cement (Dec. 1904), and which is apparently not intended to apply to natural rock or "stone" cements, but only to the artificial product made by calcining a mixture of argillaceous and calcareous materials.

Under this Specification cement may be of three grades characterised as "Quick," "Medium," or "Slow-setting" qualities, and the specific gravity is to be not less than 3·15 when sampled at the maker's works, and not less than 3·10 when sampled after delivery to the consumer, but it is not stated whether this applies to one only of the different grades or to all three.

The grinding must be such that a residue of not more than 3 per cent. is left on a sieve of 76 × 76 meshes per square inch, and not more than 22½ per cent. on one of 180 × 180 meshes. The wires of which these sieves are made are to be 0·0044 and 0·002 inch diameter respectively; as these wires are finer than those given by Mr. Butler, and referred to above, they give virtually coarser sieves.

Directions as to sampling and tensile testing are given. The strength after 7 days to be not less than 400 lbs. per square inch, and 500 lbs. after 28 days. The increase in strength between 7 and 28 days to be not less than 25 per cent. in case of briquettes shewing an average of 400 to 450 lbs. in 7 days, with proportionate reductions in the increase to 10 per cent. for cement shewing 500 lbs. or over in 7 days.

The Le Chatelier boiling test for soundness is prescribed, but the Specification is very obscure on the interpretation to be placed upon the results.

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*Published by Crosby, Lockwood & Co., Stationers' Hall Court, E.C. Price 2s. 6d

CHAPTER III.

PAVING.

It has already been mentioned that the extent of road to be paved and maintained in connection with the tramway is limited in the General Act to 18 ins. outside the rails; allowing 3½ ins. for the width of the rail, this gives 8 ft. as the total width of the paved track on a single line of 4 ft. 8½ ins. gauge—the width on a double line will probably be fixed by the width of the cars, or certain other considerations and special circumstances. If the tramway be laid to a narrower gauge than 4 ft. 8½ ins., the Local Authority sometimes requires the width of marginal paving to be increased in proportion, so as to keep the total width 8 ft. in spite of the narrow gauge.

On a double line the area is affected by the width of the middle-way or space between the two parallel tracks. In the 1870 Act, the maintenance of this space only applies to its full width when that width does not exceed 4 ft.; if this be exceeded it may be assumed that the 18 ins. (or other) outer margin limit would apply to each line separately.

On any tramway the minimum width of this intervening space is fixed by the width of the cars in a somewhat roundabout way. The Standing Orders of both Houses of Parliament direct that the plans shall show the distance between the centre lines of the double line, and at this distance "must in all cases be sufficient to leave at least 15 ins. between the sides of the widest carriages and engines to be used on the tramways when passing one another." The width of the car is fixed by the Special Act. On a wide gauge tramway with cars 6 ft. 10 ins. wide, this minimum width would be about 3 ft. 6 ins.; a middleway of this width on a 3 ft. 6 ins. gauge tramway would admit of the use of cars 5 ft. 9 ins. wide only; wider cars could only be used by making a proportionate increase in the width of the middleway. Powers have been obtained by some recent Acts to use on old tramways cars of a greater width than is fixed by the 15 ins. limit. The cars, however, have to be subject to the Board of Trade's approval, and that will not be given unless the lines are altered where necessary to give the 15 ins. intervening space.

There are certain special provisions made to apply whenever the plans require the rails to be laid at a less distance than 9 ft. 6 ins. from the edge of the footpath, and the Local Authority generally requires that the whole of the space where this less distance occurs shall be paved and maintained in the same manner as the rest of the surface within the usual limits. If this less distance be on a single line section of the tramway, the Board of Trade requires* it to be laid as a double line with cross-overs so that the traffic may be diverted from one line to the other to avoid casual obstructions: this seems to be an excellent arrangement, but it is of no practical effect, because moveable points that are not used pretty frequently are seldom ready for use when they are wanted. Sometimes these double tracks have to be laid as interlacing lines, or else placed so closely together that only one of them can be used at the same time: in any case they are so laid that the full space of 9 ft. 6 ins. is obtained on the one side of the road or the other, whichever track is being used. It is obvious that a long length of tramway constructed under these conditions may cause a serious increase in the cost of the works: there will be only the traffic facilities of a single line, but the cost will be more than that of a double line; if the road is wide enough for a single but not for a double line, the cost of the extra paving on a passing place 3 chains long will probably exceed £150, or more than £1,000 per mile of route with passing places spaced about six to the mile.

Practically there are only two classes of tramway paving in England, stone and wood, other materials, such as asphalte, tar, macadam, &c., are used to such a limited extent as not to call for notice. The stone used is nearly always some form of granite. Sandstone is useful in places where the gradients require a rough gritty surface, but it is not hard enough for use except under such special circumstances as make its durability of less importance than its other qualities. The nature of the surface is the essential point in this question of road maintenance; it must be suitable for the traffic and therefore it must be sufficiently rough on a gradient. Roughness and durability are only consistent with each other to a limited extent, and a hard durable stone is very apt to wear smooth. A new feature in this question of surface maintenance has recently been introduced by the decision in the dispute between the Dublin Authority and the local Tramway Company; here, after protracted litigation, it has been held that if the surface is not sufficiently rough to satisfy the Local Authority the Company must keep it sanded.† The relief given by sprinkling sand on granite is of course quite temporary; it is soon blown or wasted away and the principal effect of using it is to still further polish the granite surface and the sanding has to become a perpetual process. Under these circumstances it is quite possible there would be economy in using a less durable stone if it were sufficiently rough to render the sanding unnecessary.

A stone which is neither a sandstone nor a limestone is generally called "granite" when used for road making. This appears to be a trade custom, but it is misleading, inasmuch as the rocks so called differ very widely in structure and composition, and the word granite properly applies to a few of them only, viz.: those whose three principal constituents are quartz, felspar and mica. It is usual to specify the composition of the rails with great minuteness; the quality of the paving materials is of equal importance in the work, but it is not possible to secure any desired quality by specifying a composition for the stone. Some of the mineral constituents of the stone are not so hard and durable in their nature as others, but their absence may not be an advantage. The stone is made up of different minerals, which may be identified in any given case with more or less certainty, but the minerals themselves are not very constant in chemical composition, nor in their principal properties* : the felspar in one rock may be nearly as hard and durable as the grains of quartz, but in another they may be soft and friable, and the rock quite useless as a paving stone. Mica is a soft flaky mineral with no wearing properties at all, it is present in all true granites. In some it is so plentifully distributed as to render the stone quite useless; in others it serves a very useful purpose, as there is just enough of it to keep the exposed wearing surface in a roughened condition. The mineral composition of some of the most common paving stones is given in the following table, which has been compiled from various sources :—

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* In some recent Acts these cross-overs are to be laid "if the Board of Trade requires."

† This decision having been confirmed by judgment of the House of Lords, 27th November, 1902, must be regarded as final.

Locality.	Quartz.	Potash Felspar. (Orthoclase.)	Mixed Felspar. (Plagioclase.)	Mica.	Hornblende.	Augite.	Magnetite.
Penmaenmawr	Q	...	P	...	H	...	T
Yr Eifl (1)	Q	O	P	M	H	A	M
Llanbedrog	Q	...	P	...	...	...	...
Pwllheli (2)	...	...	P	...	H	A	T
Clee Hill (3)	...	...	P	...	...	A	M
Rowley Hills (4)...	...	...	P	...	...	A	M
Threlkeld (5)	Q	O	P	...	...	...	...
Mount Sorrel (6)	Q	O	P	M	H	...	M
Markfield (7)	Q	O	P	...	H	...	M
Groby (7)...	Q	O	P	...	H	..	M
Stoney Stanton (7)	Q	O	P	...	H	...	M
Dalbeattie (8)	Q	O	P	M	H	...	...
Sclattie (9)	Q	...	P	...	...	...	...
Tyrebagger	Q	O	P	M	...	...	...
Tilliefourie	Q	O	P	M	...	...	...
Cornish	Q 40%	O 24%	P 13%	M 10%	... ...	... ...	... ...
Newry (8)	Q	O	P	M	H	A	M
Anghrim	Q 32%	O 9%	P 37%	M 7%	... ...	... ...	... ...
Trevor	—	—	—	—	—	—	—
Hardness	5·5 to 7	6	6	2 to 2·5	5 to 6	5 to 6	5·5 to 6·5
Specific gravity	2·5 to 2·8	2·6	2·6	2·8 to 3·1	2·9 to 4·0	3·2 to 3·5	4·9 to 5·9
Fusibility...	Inf.	5	3	Diff.	3	3	Inf.

REMARKS.

(1.) Quartz diorite.
(2.) Felspar porphyry.
(3.) With olivine—basalt.
(4.) With olivine—fine grained basalt.
(5.) With calcite and epidote.
(6.) Hornblendic granite.
(7.) Syenite.
(8.) Coarse grained granite.
(9.) Fine grained.

P, in felspars indicates type of crystalisation, and includes several distinct kinds of felspar.
T, = Titaniferous magnetite.

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* The physical properties of the different minerals are taken from Collins' Mineralogy.

No statement such as this table can be final for several reasons. In the first place some of the minerals mentioned occur in very small quantities only, and not being regularly distributed throughout the rock may escape notice in any specimen taken at random; secondly, the minerals themselves are irregular in composition, colour and crystaline form, and they cannot always be identified with certainty. Some of them seem to be liable to a gradual alteration under conditions that cannot be exactly defined, but of which the effects of weathering may be one of the most important. It is very likely that to this slow process of alteration should be ascribed some of the variations in hardness, specific gravity, colour, chemical composition and other properties which make any short and comprehensive description quite impossible. The one thing common to all these paving stones is that they belong to the volcanic or igneous rocks. They have all been solidified by cooling from the molten state : when in this state of fusion the separate minerals would not exist; their constituent elements would be all mixed up as a confused mass in some kind of solution; as the rock cooled higher compounds would be formed and separated by a crystalising process from the fluid mass. The minerals are believed to crystalise out in the order of decreasing basicity; *i.e.*, those successively formed will contain ever-increasing quantities of the acid constituent, silica;* quartz would therefore be formed last, and may be taken as a kind of solvent for the others. This process would be regulated by the conditions of temperature, pressure, viscosity, movement, rate of cooling, &c., which probably would vary from place to place; any variation in any of the conditions being likely to cause some differences in the resulting rock. In a general way rapid cooling would result in small crystals of many varieties and slow cooling in large crystals of much smaller variation in composition.

Granite Paving.—

Setts are bought by weight, and the cost of the finished work will be affected by the area which can be covered by one ton of the stone. This will not only depend upon the depth of the setts, but upon their size and perfection of dressing, and the specific gravity also. A roughly dressed sett cannot be laid with very close joints, and therefore a ton of such will cover a larger area than would be covered by the same weight of better dressed materials. Again, the smaller the setts are when the depth is fixed, the larger will be the proportion of space taken up by the joints, and the greater will be the area covered by a given weight. Taking a stone of medium specific gravity, such as Enderby, it will be found that setts 3 ins. wide and 5 ins. to 8 ins. long will weigh as nearly as possible 1 cwt. per square yard for every inch in depth. One ton of 5-in. setts will therefore cover 4 square yards, and the like weight of 6-in. setts will cover 3·33 square yards. This corresponds to an average specific gravity of 2·40, whereas that of the rock itself is about 2·70; there is therefore about $\frac{1}{9}$th, or say more than 10 per cent., of the total space taken up by joints.

The specific gravity and weight of some well known paving stones are given in the following table, which has been compiled from various sources :—

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* Dr. Joly, in Proc. R. Dublin Soc., Vol. IX.

Locality.	Specific Gravity.	Weight per cu. ft.
Aberdeen	2·62	164
Peterhead	2·69	168
Dalbeattie	2·70	169
Dalkey	2·76	173
Newry	2·70	169
Quenast	2·70	169
Guernsey	3·04	190
Penryn	2·96	185
Penmaenmawr	2·75	172
Do. (grey stone)	2·82	176
Port Nant	2·70	169
Pistyll	2·60	162
Yr Eifl	2·63	164
Llanbedrog	2·53	158
Gimblet Rock	2·90	178
Mount Sorrel	2·63	164
Enderby	2·70	169
Markfield	2·83	177
Sapcote	2·73	171
Groby	2·65	166
Stoney Stanton	2·69	168
Clee Hill	2·87	179
Threlkeld	2·63	164
Shap Fell	2·73	171

It will be seen that the difference in weight between the heaviest and the lightest stones amounts to more than 30 lbs. per cubic foot, or about 20 per cent. of the weight of the lightest stone in the list. The covering powers of the stones obviously differ in a similar manner, and any statement of the areas covered by setts of different sizes can only be of service when the weight or specific gravity of the stone itself is known.

The depth of the setts is generally 1 in. less than the depth of the rail to be used with them; the width very seldom less than 3 ins., or more than 4 ins.; the length should not exceed 8 ins., as a long sett is very likely to rock upon any specially hard unyielding point in the bedding. A width of 3 ins. to 3½ ins., and a length of 5 ins. to 8 ins. are the best dimensions for general use. The engineer's or surveyor's personal opinion counts for something in this matter, and it must be admitted that quite satisfactory work may be done with setts whose sizes are not within the limits stated. There is no room, however, for difference of opinion in the statement that, for good neat work, whatever the sizes may be, the setts must be true and square, with cleanly cut arisses and reasonably flat surfaces on all sides, with no deep hollows or lumpy projections. When stacked together as closely as possible, the width of four courses should not exceed four times the specified width of the sett by more than an inch. It is furthermore of primary importance that the setts be not wedge-bottomed; some engineers specify that the area of the bottom surface of any stone shall not be less than three-quarters the area of the top. In another way the same end may be obtained by specifying that the length of any bottom edge shall not be more than half-an-inch less than the corresponding top edge. The bottom surface should be flat, and with sharply defined arisses along the sides and ends.

A good concrete foundation is essential to any paved roadway; the paving, granite or wood, is only a renewable surface dressing, and its shape and permanence depend entirely upon the foundation on which it is laid. The most rational way of securing a satisfactory finished roadway will therefore be to finish the concrete with a fair and even surface, and then cover it with a pavement layer of perfectly uniform thickness. When wood is the paving material, this is the recognised practice; but granite setts cannot be cut to the shape and uniformity of wood blocks, or of bricks made in a mould. So long as any regard whatever is paid to cost, *some* irregularity and variation must be admitted. Hence it is necessary to place a certain thickness of packing or bedding under the setts to allow for the inevitable variations in depth. This being admitted, it is usual to assume that there is no necessity whatever to finish off the concrete with an even surface, as a layer of bedding has to be provided anyway, it may just as well compensate for irregularities in the concrete surface, as well as for irregularities in the depth of the setts. It does not require much argument to demonstrate that success cannot be depended upon in this way of carrying out work; a bedding of unequal thickness will be subject to unequal compressions and, at the best, the roadway surface can only show a rough sort of mean between the irregularities of the paving setts and those of the concrete surface.

The only way to ensure a satisfactory pavement is to bring up the concrete to a smooth even surface, to use a thin layer of bedding, and then take care that the setts laid upon it are as nearly as possible of a uniform depth. Tramways as a rule will not stand the cost of much fancy work in having the setts chiselled over to exact size and shape. Sometimes a certain amount of "special dressing" is carried out upon the setts laid in contact with the rails, but it is doubtful indeed if the extra quality of pavement obtained by such mason's work in other parts of the roadway is worth the extra cost, especially when very nearly the same result may be obtained by special sorting.

It will be found that a quantity of setts from the quarry which are supposed to be true to ¼ inch in depth, can be sorted into four or five separate grades, differing about ⅛ inch from each other, quite apart from those which have to be thrown out as being too "lumpy" or having "wedge bottoms." If these grades are used by themselves in large definite patches upon a properly surfaced concrete foundation, the layer of bedding need only be sufficiently thick to allow for the irregularities in the surface of each particular sett, which is quite a different thing to having to allow for variations between the setts themselves. The bedding will therefore be uniform in thickness; it will compress regularly under the traffic, and the surface of the pavement will be even and regular also, and remain so. Such a pavement will be vastly better and easier to maintain than it would be if the same setts were used mixed up together. In such cases all the skill of the paviors and their rammermen is required to conceal the imperfections and irregularities of the work: truth to tell, practised workmen are generally skilful enough to do this until the road has been thrown open for traffic, and then they are soon called for again to make repairs.

It is difficult to make any comprehensive statement dealing with the *wear* of the granite setts composing the pavement on any given tramway; apart from the material itself, the amount of wear depends upon so many different factors. It has already been indicated that the hardest and most durable rocks are not suitable for gradients beyond certain limits owing to the slippery nature of their surface when worn by traffic. Circumstances must determine what these limits are, and what may be deemed suitable for a certain gradient on one road, may be quite unsuitable for the same gradient on another road, owing to the difference in the traffic. So far as the material itself is concerned the granites from Guernsey and Yr Eifl may be taken as typical hard stones. Perhaps Penmaenmawr and Clee Hill are equally hard, but they are not equally *tough;* their brittleness is a grave defect on a tramway of any kind. The granites from Aberdeen, Mount Sorrel and other Leicestershire quarries would be typical hard stones of a lower grade of hardness. Below them would probably follow other Welsh stones such as Pwllheli and Llanbedrog, and softer still would rank Newry and Dalbeattie. These, however, would be far before sandstones or limestones in respect of hardness and durability, though perhaps not in respect of certain other qualities. No rigid classification is possible, as specimens of rocks from one district may differ as much amongst themselves as they do from rocks from quite another district; and again no such classification could take fully into account the variations in conditions under which the rocks have been, or are proposed to be, used.

It is certain that the most important factor determining the wear of the pavement on a tramway, and the "life" of the setts composing it, is the nature of the traffic upon the tramway and not that upon the roadway.

Welsh setts have been found to wear away under the heavy street traffic of Liverpool at the rate of $\frac{1}{50}$th inch per annum, or say, 1 inch in 50 years Tramway rails under very moderate traffic wear away much faster than this, and have to be replaced more than once during the life of a granite sett under normal conditions in an ordinary pavement. This is not so on a tramway. In an ordinary paved street a granite block remains where it is placed; it is firmly supported against those around it, and it is submitted to a wearing process on its upper surface only. It will remain in this position for many years, and when taken up will probably be found to be flatter on the top than when first put down. It is practically impossible that this can be so on a tramway, at least where any form of mechanical traction is in use. The Tramways Act, 1870, directs that the rails shall be kept level with the surface of the roadway. In practice, the difficulty is found to be in keeping the roadway level with the rails by taking up and relaying the setts. A few displacements of this kind will probably do more damage to them than many years fair wear on the top surface only.

Light cars, such as those used with animal traction, have but little effect upon the adjacent roadway; the vibration they cause is negligible on a well laid track, and the rail itself may be worn away more rapidly than the stone setts. In exceptional cases, and where specially soft setts are used, they may be fairly worn away enough to justify extensive repairs before the rails require attention. In such cases the setts may be re-inforced by the use of chilled iron paving blocks, alternating with them alongside the rail. It is all a question of the relative effects of the different kinds of traffic.

When mechanical traction is in use the conditions are quite different. The heavy vehicles set up a vibration in the rails which appears to be absent, or at least non-effective with lighter loads. The vibration is communicated to the paving, and in time this and the rail itself become loosened, and the bedding or concrete immediately beneath them is disintegrated. In making repairs the arisses get broken away on the setts, and a large proportion of them have to be discarded as "worn out," and replaced by others when the actual reduction in their depth may be too small to be noticed.

When a rail becomes sensibly loosened, it may affect the adjacent paving setts in either of two ways: it may cause them to sink below its own level, or it may cause them to work upwards above it. The first named effect is facilitated by the setts being of insufficient depth, and having too much bedding beneath them. Water accumulates under the rail, and is forced out by the passing traffic into the bedding under the setts; the cavity under the rail is in such a position that this is the readiest channel for its escape. If any appreciable proportion of the joints between the setts, or between them and the rail, is open, the fine stuff at least in the bedding is washed away, and the pavement must sink. On the contrary, if the setts are close jointed, and there is no ready escape for the water when the surging takes place, the pavement is lifted. If the service is a frequent one, other traffic is crowded off the track, and the setts have but small chance of being forced back again into place. The cavity underneath may become silted up, and the pavement will continue to work upwards, until it becomes necessary to break it up and relay it at a more suitable level.

That this movement of the pavement, rising or sinking, is due to the tramway traffic, is shown by the fact that it does not occur in an unused tramway, however heavy the ordinary traffic may be. It may be traced at once, *firstly*, to the joints and bedding being disintegrated by vibration set up in the rails; and *secondly* to the surging action of water washing away this loosened matter: both are effects of the tramway traffic only. When this fact is not recognised, the law requiring the tramway company to maintain a certain portion of the roadway, "which they do not run upon," is often taken as a text to show the hardships and burdens thrown upon the company. It might be possible to contend that the tramway traffic is a public necessity, and the wear and tear caused by it should therefore be paid for out of the same funds as those provided for dealing with the effects of ordinary vehicles, but this is quite another line of argument: we are concerned here only with the relations between physical causes and their effects.

Wood Paving.—

Wood is used as a paving material on a tramway because of its comparative freedom from noise: in any other desirable quality every variety of it is inferior to granite. It is not so heavy and it is therefore less stable and more easily affected by vibration arising in the rails. It wears faster, and therefore has to be relaid and replaced more frequently. This greatly increases the cost of maintaining the line, and the question to be determined in any case is whether the extra comfort afforded by the wood pavement is worth the extra cost of maintaining it; regard being had to the fact that those who benefit by the extra comfort may not contribute anything towards the extra cost. The experience of an ordinary road is not of much service in settling this important question : wood blocks, say 6 ins. deep, can be laid down and left undisturbed until half their depth has been worn away before it is necessary to renew them, and then their renewal will be necessary, not because they are really " worn out," but because they have worn so irregularly that the bumpy surface cannot be properly cleaned and generally is too great a nuisance to put up with. During this time the expense of maintenance and casual repairs may differ but little from the figures due to a granite pavement. On a tramway the rails maintain a uniform level, and when the wood blocks adjacent to them have been worn away to the extent of half an inch or thereabouts, they must be dug up and relaid at a more suitable level. It is seldom indeed that these repairs amalgamate properly with the undisturbed work and become permanent; too frequently they soon have to be done again, and the expense of maintenance becomes a very heavy charge upon the tramway revenues. This is a matter which has not received adequate consideration in some tramways of recent construction, and will be a troublesome thing to deal with when the effects of wear and tear have to be made good.

For building and general engineering purposes timbers have long been classed as either *soft* or *hard* woods : the former being cut from the pine, fir, larch, and other cone-bearing trees. The "hard" woods include all other woods, such as elm, beech, oak, &c. These latter are also called "leaf" woods, perhaps because the leaves of the soft wood trees are more like spines or needles. For paving purposes the " soft " woods are as above defined, but by " hard " wood is generally understood the Australian Jarrah or Karri timbers, or some other foreign wood of a similar general character, such as Black-butt, Mora wood, and a few others which have been used in a more or less experimental manner. The English hard woods play but a very subordinate part. Oak and beech have been used to a limited extent in several towns, but it is not likely that they will ever be generally used : the supply is a very limited one, and even if such woods could be obtained in unlimited quantities it is doubtful if they would be found superior to the Australian woods in the essential qualities of durability and uniformity of texture.

Soft Wood.—

The hardest and strongest of the " soft " woods is *pitch pine*, its straight grain and resinous nature have perhaps frequently led to it being used for paving blocks. It is however not a good wood for paving purposes, being too irregular in hardness and consequent durability; the soft parts wear away so much quicker than the harder sections that the road surface soon becomes uneven. The wood most generally used is that known as " yellow deal," and is, or should be, cut from the " northern pine." White deal, or spruce, cut from certain fir trees, is softer and of more open grain. It shrinks less than the pine wood, and may be an ideal wood for use in places where it is not submitted to actual wear and tear, but it is distinctly inferior in durability to the yellow deal.

The specification for supply of the blocks will provide that the timber be properly seasoned, close and uniform in grain, free from sapwood, shakes, and large or loose knots. As to seasoning, due regard must be given to the use to which the wood is about to be put; it is not intended for internal work, and subsequent shrinkage is not nearly so mischievous as expansion. The shakes and loose knots can be easily detected, and faults of this kind must be very bad indeed if they exercise any material influence on the life of the pavement. The most serious defect is the prevalence of immature sapwood : it is soft and most liable to decay, and is the first part of the surface to wear into holes. It is the defect which has most influence in determining the "life" of the pavement. The exigencies of tramway work do not alter this fact : repairs are rendered necessary because of the condition of the worst places in the pavement, and the defect in the material which causes premature decay, or something very much akin to it, is the one which has most influence in running up the cost of maintenance. Sorting the blocks is a poor way to eliminate the faulty material; it is best to guard against it by careful inspection of the planks before they are cut up.

Uniformity of texture should not only be a characteristic of each block, but should extend throughout the bulk of the material. It will probably never be possible to get this, but it is an ideal to be aimed at, for lack of this uniformity is one of the greatest practical defects in wood as a paving material. It therefore seems to follow that, on any particular work, the timber should as far as possible come from the same district, be of uniform age, and have been through the same processes of seasoning, conversion, and exposure. The ordinary classification of timber into 1sts, 2nds, and 3rds is not of much service to an engineer with an interest confined to the suitability, or otherwise, of the timber for paving purposes.

Creosoting.—

It is but rarely that the deal blocks are required to be creosoted under pressure; it is very doubtful if the process is worth the extra cost, especially for tramway work, when it is practically certain that the life of any individual block will be shorter than if it formed part of an ordinary road surface. Creosoting is an excellent preservative against decay; but when the blocks are worn out, either through fair wear and tear, or through frequent disturbances, in a less time than is necessary for decay to set in, the precautions against that decay are thrown away. Sometimes the wood is creosoted for roads of light traffic on the assumption that decay would have a greater influence than wear and tear before the blocks are worn out; and at other times it is used on sanitary grounds, and because creosoted blocks absorb less water, and therefore dry more quickly. This will at times be quite a sufficient reason, but in ordinary roads and streets upon a tramway route, the necessity for the extra expense does not appear to be well made out.

It is more usual to " dip " or " pickle " the blocks in creosote oil; it cannot be claimed that this process has any appreciable effect on the life of the pavement, but the blocks are said to keep better when stacked for storage, and they certainly take the pitch grouting better when they are laid. The process, however, has one very objectionable feature when the timber has not been previously selected; it hides most of the imperfections and makes green and sappy blocks look very much like good material. Inspection is not of much use after the blocks have been dipped;

but granting that the timber is sound to start with, the pickling process is an advantage.

The oil that is used for this purpose is the heavy creosote oil obtained from the distillation of coal tar. There often appears to be an uncertainty in the minds of those who have to use tar and some of its products for paving works as to what these materials really are, and as a consequence, terms of uncertain meaning are used in expressing their ideas. It may, therefore, be useful to indicate what is meant by the terms here used in referring to these substances.

The thick black viscous fluid taken from the gas works to the tar distillery is a body of extremely complex composition. It is put into huge iron stills of many tons capacity and slowly heated by fires at the bottom. Steam may be used also, and the process may be assisted by the air-pump, &c., but these details do not affect the general principle. As the temperature rises the constituents of the tar are driven off in succession according to their respective boiling points, and collected in a condensing apparatus. Some of these constituents are volatile and pass over before their proper boiling temperatures are reached; they may also lag behind, for it takes time for the vapours to completely escape from the great bulk of a viscous liquid. Hence this first rough process will not effect their complete separation; in the main they will come over in the order of their boiling points, but at any particular time and temperature the vapours given off will be mixed with substances belonging properly to both a lower and a higher grade, and a further process will be necessary to separate them.

The vapours that are thus driven off in distillation are divided into two classes. The first constitute the "light oils" or "crude naphthas," and are driven off at temperatures below 400° Fah., or thereabouts. They contain the benzols, some part of the carbolic acid and many other substances useful in the arts, but not in paving or in creosoting timber. This section of the distillate is lighter than water, and if the process were stopped at this point, there would be left behind in the still the "refined tar," of special value to mix with crushed limestone, Kentish ragstone, &c., to form "asphaltic limestone," "tar macadam," and such like mixtures used for paving footpaths, and in some places the carriage-ways of streets of light traffic.

If the distillation is proceeded with the total product driven off between 400° Fah. and 700° Fah., or over, is the "creosote oil" referred to, and what remains behind in the still is the ordinary "pitch" of commerce. Otherwise, the oil is the "refined tar" minus the "pitch"; it is also called "heavy oil," because it is heavier than water, and for some reason or another it has been called the "dead" oil of tar. It is a body of extremely complex composition, and its constituents distilling at the higher temperatures are judged to be the most valuable in their antiseptic and preserving qualities. One of them is anthracene, the source of artificial madder, a dye giving the colour known as "turkey red." As this is not now a fashionable colour there is no longer profit in extracting the anthracene, and it is consequently frequently left in the pitch.

The creosote oil thus described is the material used in "dipping" or pickling the paving blocks. It penetrates but a very small distance below the surface; any local extra penetration may be taken as evidence of some defect, such as cracks, shakes, or a specially open and porous texture.

In creosoting proper, the blocks are stacked in strong closed receptacles, the oil introduced, and the temperature raised to about 220° Fah. The oil is pumped in at a pressure of 100 to 120 lbs. per square inch until the wood has absorbed the specified quantity. It may be made to take up over 12 lbs. per cube foot; but 10 lbs. is the usual quantity specified, and some engineers are satisfied that less, say 8 lbs. per foot, is sufficient. There is no recognised standard or uniform practice in this matter. It may be remarked, however, that a large injection of creosote is objectionable, as a proportion of it may ooze out of the wood afterwards, and is then liable to soften the pitch used for grouting the joints.

It is not possible to give any direction by which the quality of the oil may be readily detected in the simple way in which Portland cement may be tested for instance. The quality can only be ascertained by an analysis carried out by a person accustomed to such work. It is usual to specify that the oil shall be completely liquid at 100° Fah.; that it shall contain not less than 25 per cent. of constituents that do not distill over at 600° Fah., and not less than 8 per cent. of tar acids, and shall be free from ammoniacal liquor and water. For most purposes it is sufficient to deal with a reliable firm, and let the distiller know the purpose for which the oil is required. Practical men profess to be able to judge the quality by swimming a small quantity round a clean china plate or saucer; the very thin film of oil left on the surface should be clear and uniform in colour, free from dirty black specks, and from a peculiar crinkly movement said to indicate the presence of water.

The usual depth of the blocks is one inch less than that of the rails, and the concrete surface should be floated to such a level as to leave the top of the newly laid blocks about ⅜ in. above level of the rails with soft wood, and about ¼ in. above with hard wood. The sharp edge of the new blocks is only a temporary obstruction; it is rounded off by the ordinary traffic in a few days, and the general level becomes sensibly the same as that of the rails.

There is much difference of opinion amongst engineers on the question of *joints*, or the space left between the blocks in laying; and also as to whether cement, or a bituminous mixture, or a combination of the two, forms the best grouting material. As to the first matter, the tendency has been drifting in favour of a close joint for some time. It is recognised that the wide joint gives the blocks an opportunity of splintering away on the edges, and so the surface of the roadway gradually assumes a corduroy formation. The joint forms a receptacle for the collection of mud, and interferes with the cleansing. It is of no assistance to the traffic, since a horse is much more likely to slip on a dirty rough road than on a smooth one. These arguments are sufficient to justify the tendency of the last few years in new work to close up the joints and lay the blocks "hard to hard." This is all very well on an ordinary road, but on a tramway there is no doubt that a moderately open joint, between ⅛ in. and ¼ in. wide, greatly facilitates the inevitable repairs, causes less waste by breakage when the blocks are lifted, and gives the clearance necessary when they are relaid. With a close "hard to hard" joint cement grout cannot be properly brushed in, and every few courses some of the blocks have to be cut and reduced in width to enable the courses to be worked in with the undisturbed portions of the pavement. If this question of future repairs could be overlooked there would be no objection to the close joint upon a tramway; but when wood of any sort is to be used as the paving material the circumstances under which the whole has to be maintained to the satisfaction of the local authority, and the reasonable requirements of the general public have to be kept in view, and they are not the same as those applying to work in an ordinary street carriage way.

Hard Wood.—

There are many varieties of hard wood more or less suitable for paving, but the chief of those in use are undoubtedly the woods from the great Australian timber trees, the Jarrah (Eucalyptus marginata), and the Karri (Eucalyptus diversicolor). If there are others equal to or superior to these, it may be that they occupy a place of secondary importance because adequate means have not been taken to push them into notice, nor to ensure a supply if a demand existed. The Eucalyptus genus of trees is said to be characterised by an oily volatile secretion in the leaves, an astringent resinous matter in the bark, and a peculiar gum in the pores of the wood. This last feature is of the most importance, because of the gum's preservative power on the wood.

Jarrah and Karri woods are both heavy and close grained, and of a very tough curly fibrous texture, which is most strongly marked in the Karri. They are of a pale red colour, something like mahogany, the Karri being the lightest tint. In their general aspect they are very much alike, and the variations in colour amongst the blocks of either one of them, may be as great as the difference between a typical Karri and a typical Jarrah. The Karri wood is the heaviest, and a block will sink in water, whereas one of Jarrah will float. Another test is burning; Jarrah leaves a black cinder behind, whereas Karri leaves a white or greyish coloured ash. For paving purposes there is very little difference between them, but the general opinion seems to be that the Karri is the better wood of the two. These two timbers are characteristic of Western Australia: 2,000 miles away to the eastward the great forest trees of New South Wales and Victoria are also of the Eucalyptus genus, and are very largely used for paving purposes, although a much smaller proportion of them reaches this country than of the West Australian woods. Of these, the "Tallow-wood" is said to be the hardest and most durable; but other admirable paving materials are found in Blackbutt, and in several distinct varieties of Eucalyptus bearing the general name of "Red gum." Other varieties of "Blue gum," "White gum," &c., are also used to a less extent. These "Red gums" are, of course, quite different from the American "Red gum" recently extensively used for paving in certain metropolitan districts.

The gum that has been referred to as pervading the pores of these woods is sometimes in excess, and forms distinct layers separating the rings due to the annual increments of growth in the tree. These may be of no consequence until the blocks have to be disturbed for repairs, when they may cause such blocks to fall to pieces. Sometimes the gum collects in masses round knots, loosening them and causing them to drop out. The gum may be of service in preserving the timber when disseminated throughout the mass, but these local accretions can only be considered as defects.

The wood is generally imported in the shape of planks 3 ins. thick and 9 ins. wide. This was the accepted standard dimension, and when cut up the timber of course made blocks 9 ins. long. The smaller timber, 6 and 7 ins. wide, was looked upon as an inferior grade. It is now generally recognised that this smaller timber is quite as good and sound as the larger stuff, and it certainly makes better proportioned blocks when it is cut up. The 9 in. blocks are more likely to rock and become loose on any irregularity in the bearing surface, and they are much more easily split in handling, or even in laying, than the shorter blocks.

With hard wood perfect uniformity, both as to depth and thickness, is of more importance in the production of neat and satisfactory work, than it is with the rough coarser texture of soft wood. As to depth, the matter is one of care and skill in cutting up the planks in this country, but the nominal 3 ins. in thickness of the planks as imported is not to be depended upon. For close jointed work the planks must be planed to a uniform thickness in a machine before they are sawn up. This may add a trifle to the cost of the work, but it is quite essential. If the blocks are to be laid with a joint ¼ in. wide, the thicknessing is unnecessary, but this method of constructing a pavement is fast dying out. For reasons indicated elsewhere the closest possible joints are not advisable on a tramway; the blocks should be laid loosely, with a joint well under an eighth of an inch in thickness, but not pressed up into close contact.

Opinions differ as to the best way of laying the blocks on the smooth concrete surface, but probably the majority of engineers prefer the "dip and lay" method. As each block is about to be laid it is partially dipped in the bituminous grouting mixture kept very hot in little portable melting pots heated by oil lamps. These are easily moved about on the newly laid pavement so that there is always one within reach of every pavior placing the blocks in position. Some engineers dip one side only; others dip one side and one end. The mixture is very hot and fluid and is expected to drain down as low as possible as soon as the block is in position, closing up all cavities and preventing the future access of wet from above. This object is not always attained; the pitch may not be hot enough, or the blocks and concrete surface may be cold and damp, so that the pitch is soon chilled and the blocks are really supported on one edge only. To prevent this other engineers dip the bottom of each block to a depth of half an inch only, and this appears to be the method most likely to give uniform results. When a good area is laid the whole surface is flushed over with the same hot mixture, so as to completely fill the joints. On tramways, in view of the future repairs, there is an advantage in using cement for this final flushing up, as the blocks are so much more easily cleaned for relaying after being lifted.

The bituminous grout referred to is a compound of pitch and creosote oil, blended in such proportion as will produce a permanently tough and elastic yet solid mixture. It is elsewhere mentioned that the oil is very complex and variable in composition, and that of the pitch is equally indefinite. The anthracene, for instance, may be in the oil, or the pitch, or in neither, and the correct proportions will depend upon the presence and whereabouts of this ingredient. Hence the proportions must be determined on the work by frequent testings. When a small quantity of the mixture is cooled, to say 60°, it should be tough and ductile in the fingers : if it does not set properly at this temperature more pitch must be added; if it is brittle, more oil is required.

The quality of the oil should be as indicated for creosoting. When it is used for creosoting timber the presence of a small proportion of water may do no great harm, but it is very objectionable when the oil has to be boiled in open cauldrons in the public street, as it causes the mixture to splutter and throw out splashes of the boiling mass. For the same reason the pitch must be kept dry, and carefully covered up in inclement weather.

The pitch should be dry and free from dirt, and in large lumps which are only broken up as required to be thrown into the boiler. When broken, the fractured surface should be bright and clean, and free from dull greasy looking spots. Practical men further judge of the quality by holding a small piece in the mouth for a few minutes, when it should become soft and ductile. If it remains hard, the oil distillation has been carried too far, and a permanently ductile grouting cannot be made with such pitch by mixing it with oil. The softness of such a mixture is too largely due to the lighter and slowly volatile constituents of the oil, and the mixture afterwards becomes brittle as they evaporate.

A pitch grouted pavement is fit for traffic as soon as the mixture is thoroughly set; say in two or three hours after pouring. To be quite satisfactory, however, it is necessary that the granite setts, wood blocks, &c., be thoroughly dry, or proper adhesion will not take place. But street work often has to be carried on when these conditions cannot be fulfilled, and cement is then likely to give better results. Water can do the work no harm so long as it is not in sufficient quantity to wash away the cement, but it will delay the setting to some extent. The great objection to the use of cement is the time required for setting; the work will really not be fit for traffic under 4 to 7 days, according to the quality of the cement and the nature of the weather. It is impossible to arrange for this in repairs; the cement is submitted to movement and vibration while the setting is in progress, and hence arises the generally temporary character of such repairs.

Where pitch grout has been used, the two great difficulties to contend with in repairs are variations in the weather, and cleaning the setts or blocks when they have been lifted. It is difficult to say which is the most difficult to deal with. It is seldom possible to delay work of repairs because the weather is unsuitable, and pitch grouting used on cold and wet paving setts never makes proper adhesion, nor holds the work in place. As to the other difficulty, chopping the pitch off the setts or blocks is a messy, tedious and expensive process, but it is the only one really available on a small scale. It is possible to clean them by boiling in creosote oil, but this can only be done to advantage on a fairly large scale in a yard; setts that have to be lifted in small patches and relaid in the place they were taken from cannot be treated in that way.

Hard v. *Soft Wood.*—

When this question is not settled by the local authority, its decision will naturally turn upon the relative ultimate costs, *i.e.*, upon the first cost as modified by the future maintenance in each case. Which will be the most economical in the long run can only be determined by careful consideration of the circumstances. The first cost depends upon the price of the wood; roughly speaking it is equal to the cost of the wood required to cover a square yard, plus the cost of excavation, concrete, laying wood and grouting, and sundry other smaller items, making a total of about 5s. to 6s. per square yard. The cost of "maintenance" in this connection is not the same as that of "repairs"; it depends upon the "life" of the wood. It is the sum, real or hypothetical, which must be set aside every year to provide for replacement when it is worn out. The use of hard wood on tramways is of such recent introduction that there is little experience to go upon.

At present soft wood blocks can be delivered at any town in the Midlands for about 2s. 0d. per cube foot. Jarrah or Karri blocks will cost about 3s. 6d. to 3s. 9d. at the same place. Excluding joints, every inch in depth of the pavement will require ·75 cube feet of wood per square yard, so that paving 4 ins., 5 ins. and 6 ins. deep will require respectively 3, 3·75 and 4·5 cube feet of timber per square yard. The cost of soft wood alone for the different depths thus works out to 6s. 0d., 7s. 6d., and 9s. 0d. per square yard respectively, and the corresponding figures for hard wood would be at least 10s. 6d., 13s. 1½d. and 15s. 9d.

Hard wood blocks 6 ins. deep at this price are out of the question for ordinary works, and the opinion is spreading that this depth is greater than it need be, even when soft wood is used. For the purpose of comparison, the cost of 5 ins. soft wood may be taken along with that of 4 ins. hard wood. Strictly speaking, also the comparison should not be made between the costs of the wood as delivered at a railway station, but between their costs as laid in the road. This item of labour, however, may be omitted, for, with soft wood, the cost of clearing the ground and laying the new blocks is approximately covered by the value of the old materials removed. This would probably not be the case if a "dip and lay" method of repairing were adopted, or if any repairs or refloating had to be done to the old concrete.

There would thus appear to be some economy in using hard wood (of 1 in. less in depth than the soft) if its "life" were half as long again as the other; the experience of its use on ordinary roads would justify this expectation and be sufficient if it applied to the first construction only, and if it could be left alone on the tramway until it was worn away to the same extent as on a roadway before being disturbed. It is quite certain that this cannot be so, and with mechanical traction the time may soon arrive when it is necessary to lift the blocks and adjust their levels to that of the rails. It may be that this process will have to be frequently repeated, and if the shallow hard wood blocks do not stand 50 per cent. more rough usage in lifting, cleaning, ramming, &c., than the deeper soft ones do, the above estimate of economy will prove to be misleading.

The following table may be useful in estimating cost and quantity of materials required in wood paving of various depths and sizes. No allowance has been made for joints in the areas to be covered by 1,000 blocks, so that the areas given must be too low. The difference may be taken to balance the loss on cutting to margins, &c.

Size. Inches.	Cub. ft. in 1,000 blocks.	Sq. yds. covered by 1,000 blocks.
3 × 6 × 9	93·75	20·8
× 8	83·5	18·5
× 7	73·0	16·2
3 × 5 × 9	78·0	as above.
× 8	69·5	
× 7	60·6	
3 × 4½ × 9	70·5	as above.
× 8	62·5	
× 7	54·8	
3 × 4 × 9	62·5	as above.
× 8	55·5	
× 7	48·5	
4 × 4 × 4	37·0	12·3

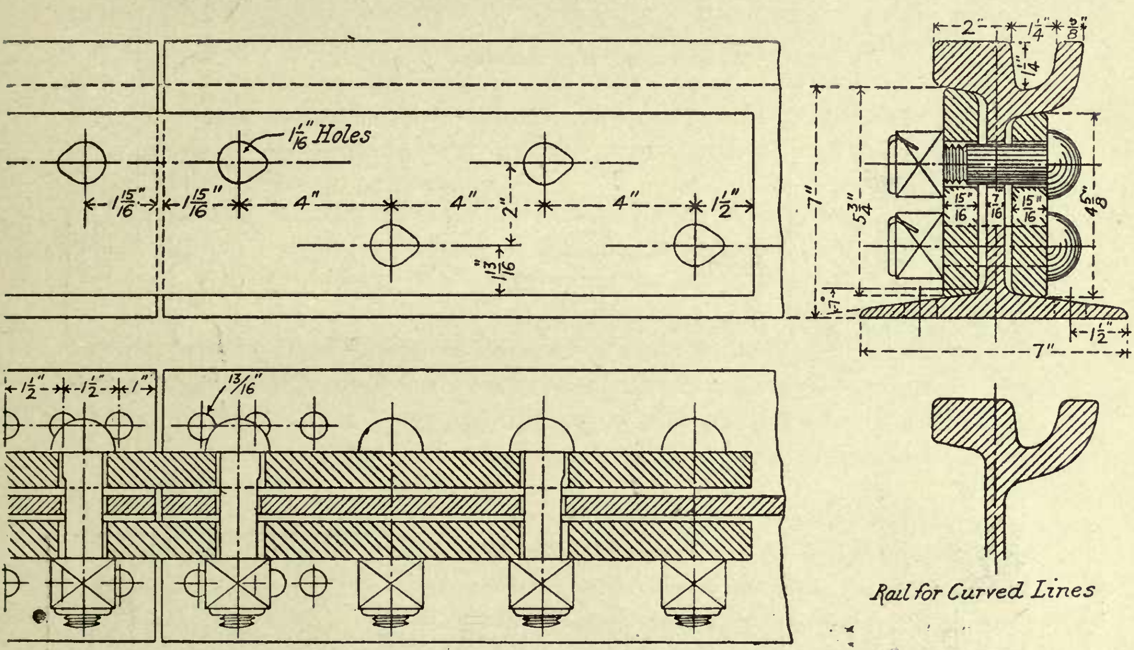

Fig. 1. Glasgow Tramways.

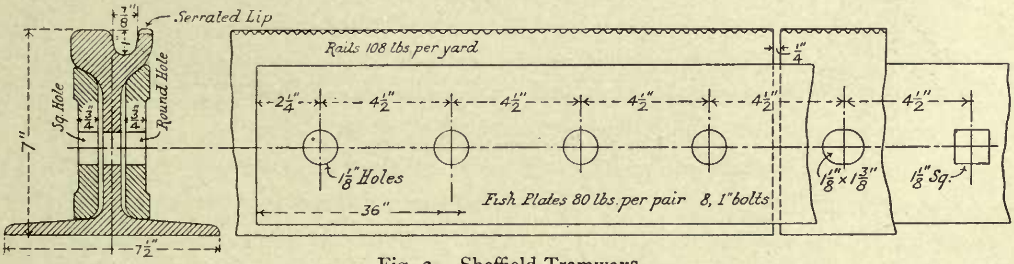

Fig. 2. Sheffield Tramways.

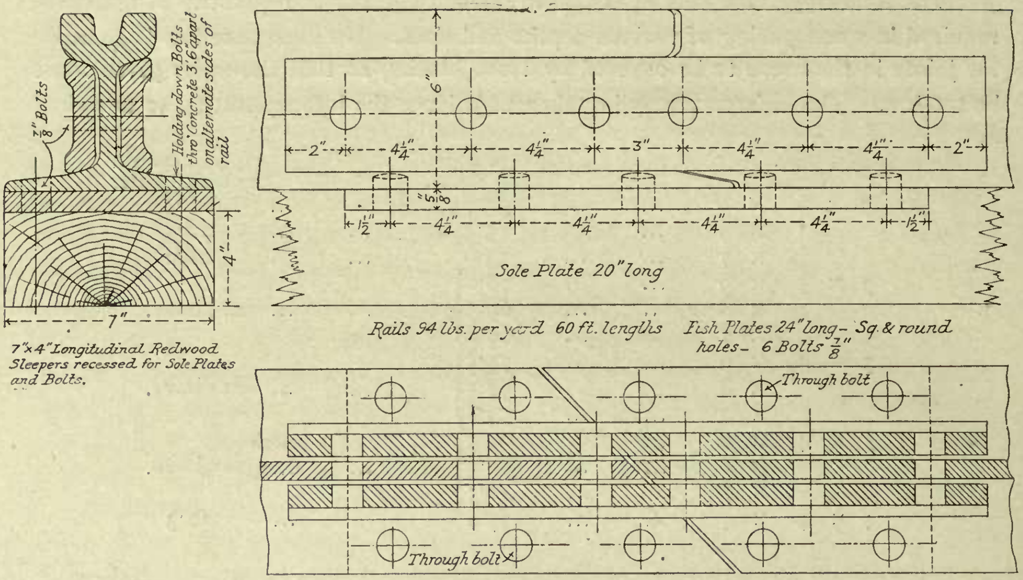
7/8" Bolts
Holding down Bolts thro' Concrete 3.6 apart on alternate sides of rail
4"
7"
7"x4" Longitudinal Redwood Sleepers recessed for Sole Plates and Bolts.
6"
2"
4¼"
3"
5/8
1½"
Sole Plate 20" long
Rails 94 lbs. per yard 60 ft. lengths
Fish Plates 24" long – Sq. & round holes – 6 Bolts 7/8"
Through bolt
Through bolt

Fig. 3. Hull Tramways.

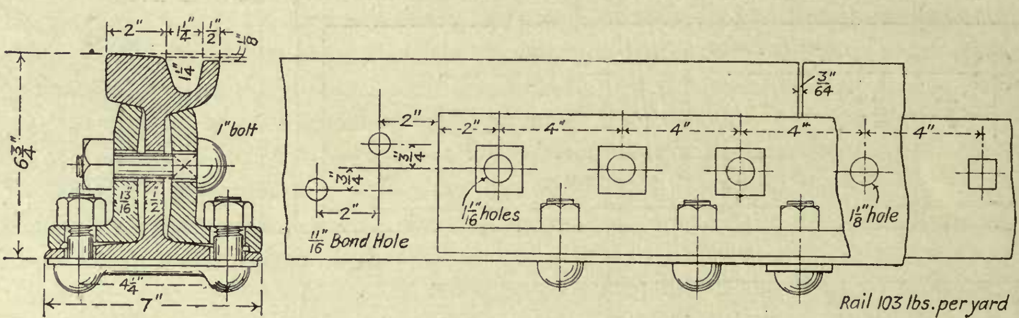

Fig. 4. Wolverhampton Tramways

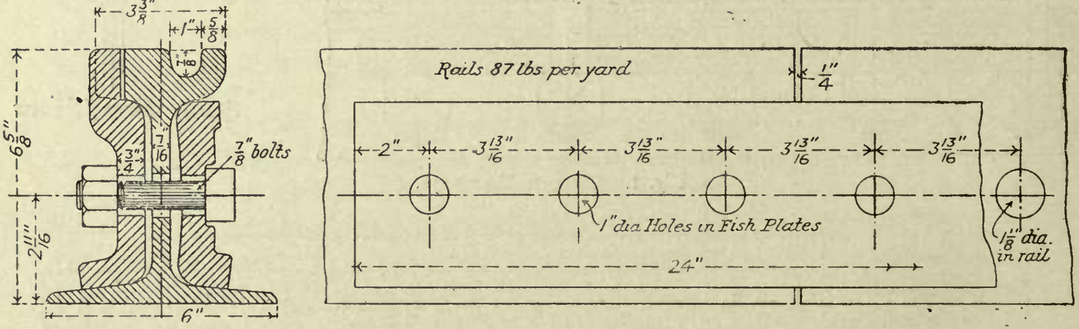

Fig. 5. Southampton Tramways.

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CHAPTER IV.

RAILS.

It is more than 40 years ago since the late George Francis Train demonstrated the practical value of street tramways in this country, and during the greater part of that time great efforts have been made towards perfecting the permanent way. A bare description of the different inventions would make a bulky volume; many of them have been brought into use, and their utility, or lack of it, thus tested; but the weak points of many of the different systems of compound rail that have been brought into use cannot be discussed.

In glancing backwards over what has been done during this period, one is struck with the obvious fact, that of all the different rails that have been used, the "girder" type is practically the only one that remains. After countless trials it has been freely accepted as the one best fitted for the peculiar conditions of a street tramway, and the variations made by tramway engineers in recent years have only been in weight, details of section, chemical composition, and such like matters. The influence of the Board of Trade and the general tendency towards standardisation in the future will have the effect of reducing even these variations to very narrow limits.

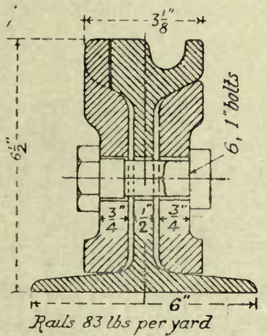


Fig. 6. Edinburgh.

Figs. 1 to 19 show various types of rail that have been adopted on some of the principal tramways of recent construction. They are given as illustrations only, and fairly represent the character of modern work. They show that the main dimensions of the girder rail vary but little; the depth is from 6 ins. to 7 ins.; the width of the head from 3 ins. to 4 ins.; and of foot from 6 ins. to 7 ins. The variation in weight is greater, and extends from 75 lbs. to 105 lbs. per yard. Examples can be found outside these limits, but they are rare.

The width of groove varies from ⅞ in. to 1¼ ins.; the higher dimensions are in favour of the tramway traffic as causing less friction in working and therefore less wear and tear and less cost in operation; the lower dimensions are due to concessions

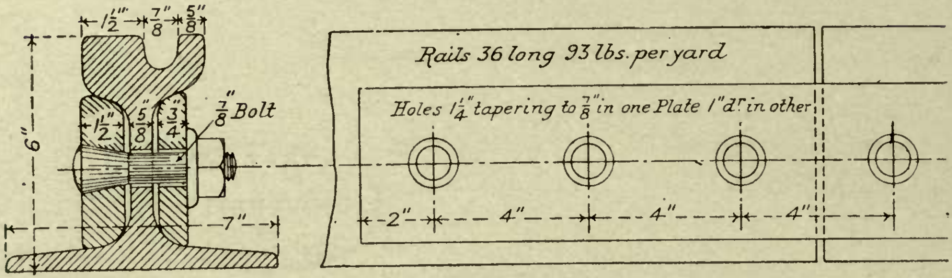

1/2"
7/8"
5/8"
6"
1/2"
5/8"
3/4"
7/8" Bolt
7"
Rails 36 long 93 lbs. per yard
Holes 1¼" tapering to 7/8" in one Plate 1" dr. in other
2"
4"
4"
4"

Fig. 7. Middlesborough Tramways.

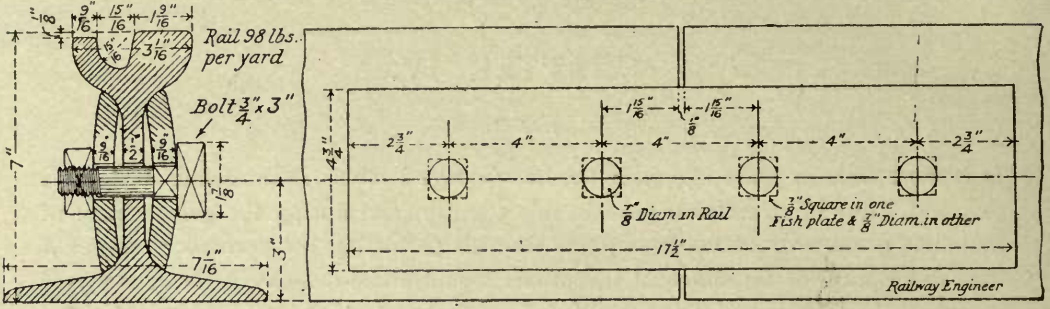


Fig. 8. Manchester Tramways.

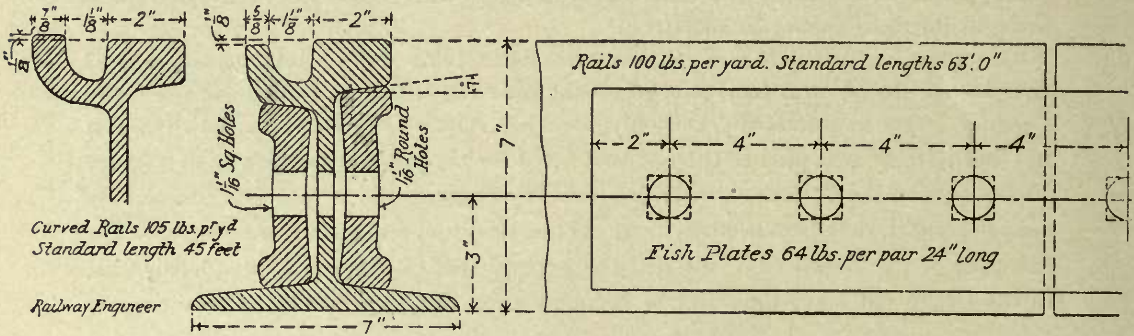

7/8"
1 1/8"
2"
1/8"
1/8"
5/8"
1 1/8"
2"
1 1/16" Sq Holes
1 1/16" Round Holes
1/4"
7"
3"
7"
Curved Rails 105 lbs. pr yd. Standard length 45 feet
Railway Engineer
Rails 100 lbs per yard. Standard lengths 63'. 0"
2"
4"
4"
4"
Fish Plates 64 lbs. per pair 24" long

Fig. 9. Manchester Tramways.

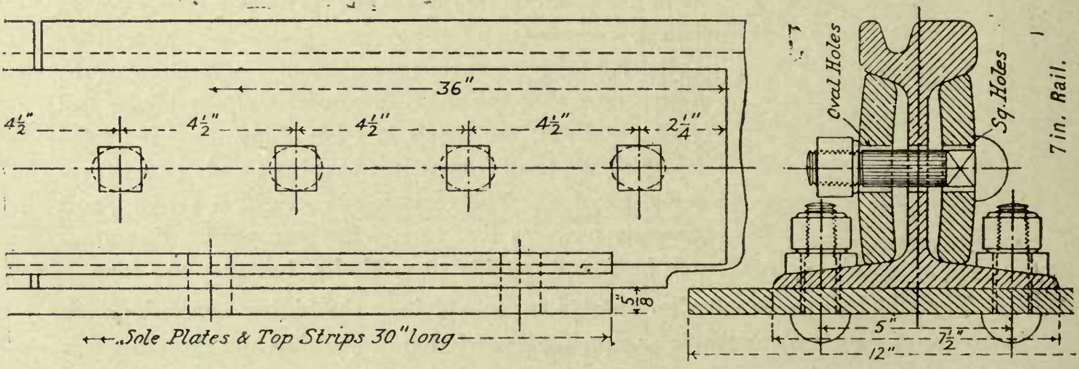


Fig. 10. Bradford Tramways.

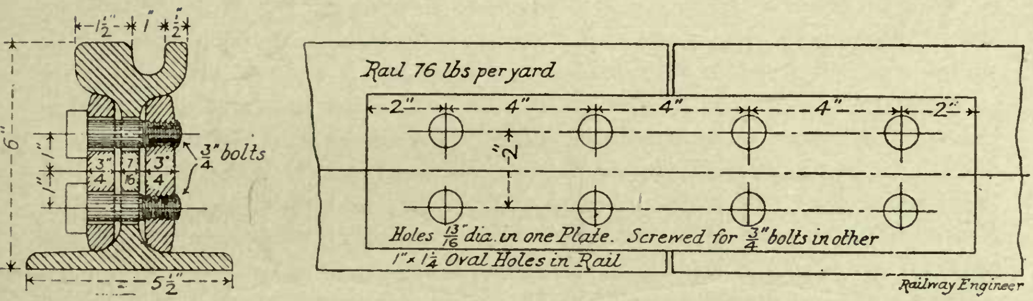

1½"
1"
½"
6"
¾" bolts
5½"
Rail 76 lbs per yard
2"
4"
4"
4"
2"
2"
Holes 13/16" dia. in one Plate. Screwed for ¾" bolts in other
1" × 1¼ Oval Holes in Rail
Railway Engineer

Fig. 11. Bristol Tramways (Kingswood Section, 1895).

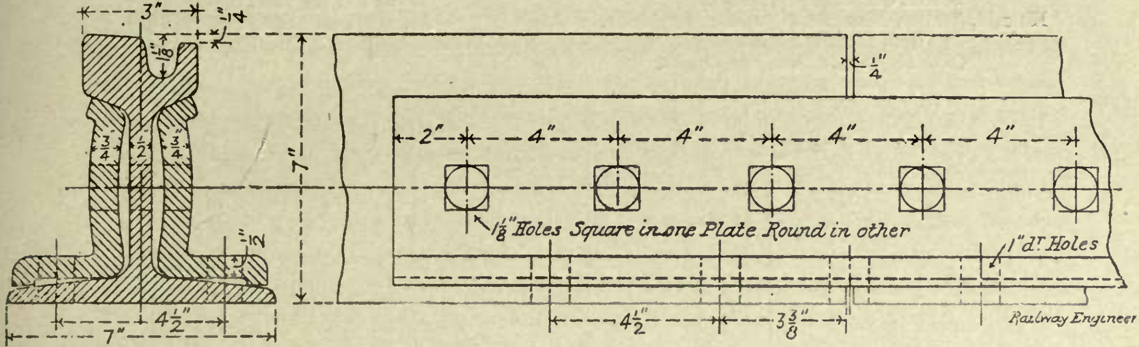


Fig. 12. Birmingham Tramways.

in favour of ordinary vehicular traffic. The Board of Trade rules limit the width to 1⅛ ins., except on sharp curves, and this is the width adopted in the standard sections. Glasgow enjoys the privilege of increasing the width to 1¼ ins. by virtue of a local Act of Parliament. On curves of less than 1 chain in radius a groove of 1¼ ins. wide is allowable under Board of Trade rules, and the standard sections provide for a lip or guard flange ⅛ in. higher than the normal for such rails, intended for use on the inside rail only. It is doubtful if the friction in passing round a curve with such a rail on the inside is any less than it would be with the normal section, but the safety is greater, since the car cannot leave the track until the inside wheels have mounted this greater obstruction. On ungrooved rails the car is controlled by the outside wheels only; on grooved rails the lip comes into action should the outside wheel flanges be for a moment lifted out of the groove, and this action is obviously all the more effective the deeper the lip may be.

On the older tramways the width of tread was generally restricted to 1½ ins. The introduction of electric traction has given rise to a demand for an increase in this dimension, so as to admit of the use of a stronger and heavier wheel, with a more efficient braking surface. Hence the adoption of a width of 2 ins. and even more in the later examples and in the standard sections. Electric traction makes tramways possible on gradients that could otherwise be worked only on the cable system, and the efficiency of the braking arrangements becomes a matter of supreme importance.

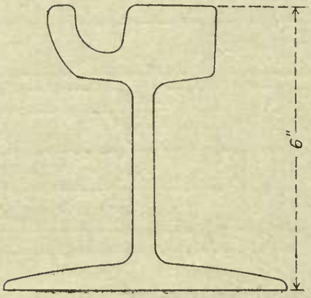


Fig. 13. 90 lbs. per yard.
Burton Corporation Tramways.
Kincaid, Waller, Manville & Dawson, Engineers.
Bath Electric Tramways,
Geo. Hopkins & Sons, Engineers.

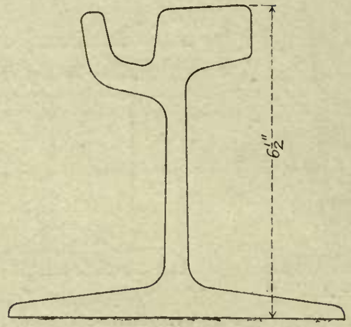


Fig. 14. British Standard Section, No. 2.
95 lbs. per yard.
Aston Manor Tramways,
Pritchard, Green & Co., Engineers.

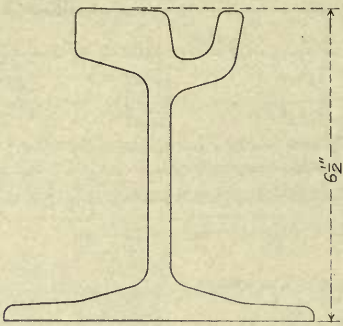


Fig. 15. 90 lbs. per yard.
Ipswich Corporation Tramways,
Kennedy & Jenkins, Engineers.
Pontypridd U.D.C. Tramways,
Reginald P. Wilson, M. Inst.C.E., Engineer.

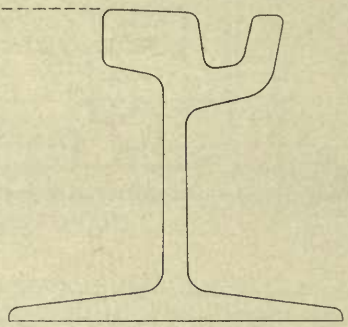


Fig. 16. 100 lbs. per yard.
Middlesex C.C. Light Railways.
H. T. Wakelam, M. Inst.C.E., Engineer

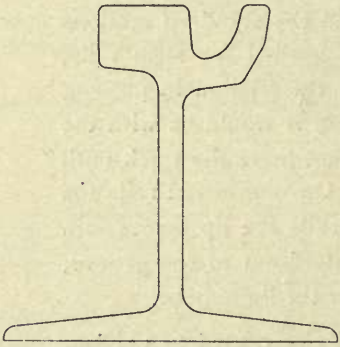


Fig. 17. 100 lbs. per yard.
Leicester Corporation Tramways,
E. G. Mawbey, M. Inst.C.E.,
Engineer.

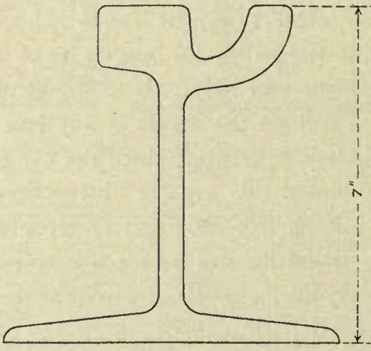


Fig. 18. 105 lbs. per yard.
Section for Curves,
Leicester Corporation Tramways.

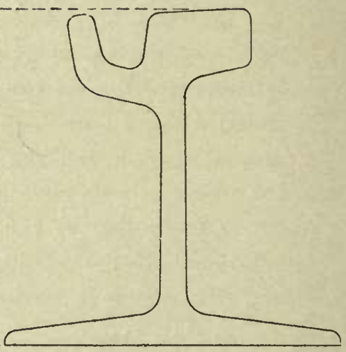


Fig. 19. British Standard Section,
No. 4. 105 lbs. per yard.
Birmingham Tramways,
John Price, M.Inst.C.E., Engineer.

There is considerable advantage in keeping the level of the lip below that of the head in a rail, and ⅛ in. is not a sufficient depression. A rail under normal conditions should not be regarded as "worn out" until a depth of ½ in. or more has been worn off the tread. If the lip was originally level it will have a greater projection than this ½ in. when that amount of actual wear has taken place owing to the outward tilting over which is always one of the effects of prolonged traffic; for a long time before this stage of wear has been reached the rail will be a serious obstruction in the street surface, and perhaps the cause of many claims for damages. Starting, therefore, with the lip ¼ in. low, for nearly half its life the rail is improving so far as ordinary traffic is concerned, and at the finish it will be but little worse than a new rail. A low lip also facilitates the escape of dirt from the groove, and thereby reduces the power required for working. The chief objection to it is the loss of grip on inside wheels on curves, but this is only of importance on sharp curves, and is easily met by providing a different section for use in such situations. With a depression of ⅛ in. only, as standardised by the Engineering Standards Committee, the effects of wear will all the sooner make the rail a source of danger to the street traffic, and so all the sooner will its owners be put to the heavy expense of renewal. A standard fixed with a view to the best interests of all parties would have been so designed as to offer the minimum obstruction to ordinary traffic over a tramway in its average condition, and this is not when it is new, but when it is half worn out.

The wear on a tram rail is the accumulated result of several influences, besides the rolling action of the car wheels. It is largely a grinding process, with fresh grit freely and constantly supplied; it is assisted by the slipping of wheels on curves, by corrosion, and by sparking when electricity is the motive power. These destructive agencies indicate that the rail should be as hard as possible, consistent with the further requirements that it shall be so tough in the grain as not to be brittle, and ductile enough to admit of being safely bent to the required curves.

The requirements of rails on a tramway are quite different from those of rails on a railway. The tramway rail is heavy and massive, capable of acting as a beam over a good wide span; it is, moreover, more or less solidly supported and bedded throughout, and its bearing surface is flush with the street pavement, so that if it did break no harm could result therefrom. On the contrary, a railway rail may be of a lighter section; is of smaller depth; it acts as a beam between fixed supports and carries heavy loads suddenly applied, and a fracture might easily cause disastrous results. The mere hardness and resistance to wear, which are the only requirements worth notice in a tram rail, are in a railway rail of quite secondary importance, and it by no means follows that the material which experience shows to be the best for a railway rail must necessarily also be the best for the other.

There has been some difference of opinion as to the process of steel making best adapted for tram rails; some engineers specify that the steel shall be made by the "Bessemer acid process," others have no objection to the "Bessemer basic process." Apart from this particular point of difference, the Bessemer process may be said in general terms to consist in blowing air through a quantity of melted cast iron contained in a huge wrought iron vessel called the "converter." This process is continued until practically all the carbon is burnt out; it is then increased to the quantity desired in the finished steel by adding cast iron, the manganic variety called spiegeleisen, powdered anthracite, or other ingredients of known weight and composition, to the known weight of fluid metal in the converter. The blast is then turned on again for a few minutes to ensure thorough mixing and uniformity of product, and the steel then poured out into the ingot moulds preparatory to being treated in the rolling mill.

If now the lining of the converter contains an excess of silica it is said to be an "acid" lining, and the process is called the "Bessemer acid process." The cast iron used as the raw material must be low in sulphur and phosphorus, as these elements are not taken up by such a lining. If, on the other hand, the lining contains an excess of "basic" constituents, such as calcined dolomite or magnesian limestone, this restriction as to the composition of the raw material is unnecessary, as the lining can combine with these objectionable impurities, and they are carried away in the slag. Iron containing substantial proportions of sulphur and phosphorus can thus be successfully dealt with in the "basic" process, and the quantities of such elements reduced to satisfactory limits. As the properties of the steel must depend upon the constituents actually present, and not upon those that have been removed, there is no reason why one process should be any better than the other.

Specifications for tram rails generally followed railway practice, and a low-carbon ductile steel was called for. This gave satisfactory results under the traffic of light horse-cars; with the more exacting requirements of steam traction results were not so good, and as electric traction is even still more severe on the rails, a harder metal is now generally required. Even with electric traction in view, however, practice has been by no means uniform, as the following table of recent specifications shows :—

Tramways.	Carbon.	Phosphorus.	Sulphur.	Silicon.	Manganese.
Manchester	·40 to ·65	·07	·07	.07	1·00
Glasgow	·55 to ·65	·06	·05	·15 to ·20	·80 to 1·00
Halifax	·28 to ·40	·07	·06	·06	
Hull	·40 to ·50	·06	·069	·10	·80 to 1·00
Liverpool	·55 to ·65	·07	·07	not under ·10	
Chester	·40 to ·50	·08	·06	traces	·70 to 1·00
B. Standard	·40 to ·55	·08	·08	·10	·70 to 1·00

It is evident that there are still wide differences as to the proper composition of the metal for the purpose, and especially as to the proper amount of carbon. This element is undoubtedly the principal one of the added constituents, and experience on tramways submitted to heavy traffic tends to show that the more of it a rail contains the better it wears, and that the upper limit is reached when the hardness interferes too much with the bending, cutting, drilling, and other works necessary to get the rails into place. It will be found that the hardness has no sensible effect on the labour required until the proportion of carbon is over ·50 per cent., and that this consideration need not furnish a reason for keeping the carbon below ·60 per cent. In the British Standard Specification the limits are ·40 per cent. and ·55 per cent. The upper limit is satisfactory, but the other one is too low, and rails of such a proportion of carbon are not hard enough to withstand the abrasive effects of street traffic. Furthermore, the variation from ·40 to ·55 is too great, and may result in some of the rails of a given batch being worn out long before the others. As the question of renewals will in all probability have to be determined hereafter by the condition of the softer rails, the "life" still remaining in the harder ones will have to be thrown away.

As to the other elements mentioned, sulphur makes the metal "hot short" or brittle when hot, and the proportion present chiefly concerns the manufacturer. Phosphorus makes it "cold short" or brittle when cold, and may interfere with bending on sharp curves, especially when the rail flanges have been punched or drilled for "anchor" pieces; the danger of fracture under traffic, as on railways, is too remote to be worth consideration. Silicon increases the hardness and brittleness, both hot and cold, but it promotes the fluidity of the metal in manufacture and thereby improves the density and homogeneity of the finished product. English engineers generally specify that it be kept below ·10 per cent., and many even below ·06 per cent., whereas American engineers require it to be not less than ·10 per cent., and others require over ·15 per cent. Small variations in the proportions of this element, and of manganese, do not appear to have much influence upon the quality of the rails.

The mechanical tests applied to a rail nearly always take the form of a "drop test"; a heavy weight falling freely upon a piece of rail supported on massive bearings. In addition to this, a tensile test on a specimen cut from the head of a rail may be required in addition; sometimes the effect of a steady bending load is to be observed, but this test is rare.

In considering this question in general terms it is to be noted that the mechanics of a drop test are by no means a simple matter, and have little in common with those of a steady load. If the piece of rail under test, supported on bearings 3 ft. apart, acted as a girder, it is clear that under a given load, doubling the length of the bearing would double the strains in the girder; under a falling weight the increased bearing might prevent the fracture of the test-piece and must therefore have reduced the stresses called forth by the impact. The length of the specimen also is of importance. It is generally specified that it shall be 5 ft. long and supported on bearings 3 ft. apart. The effect of the blow is to throw the free ends upwards; if these are long and heavy they must greatly increase the constraint in the neighbourhood of the bearings, and therefore the stresses due to the energy of the blow. In short, the resistance checking the blow is only partly supplied by the bearings; the rest of it is supplied by the inertia of the specimen itself; the proportion between the two depends largely upon the velocity of the falling weight, but there are several other circumstances that have influence on the result.

The effect to be observed is the permanent set produced by one or more blows, and the magnitude of the set is nearly proportional to the total amount of work that has been expended by the falling weight. That is to say the set produced by a 1 ton tup falling 20 ft. is double that produced by 1 ton falling 10 ft., or equal to that due to two blows from a height of 10 ft. This statement must be qualified in two ways: the weight must not be great enough to produce a set when acting as a dead load, and the natural elasticity or "spring" of the specimen must be allowed for. It will suffer a certain deformation without taking a permanent set, and the fraction of the energy corresponding to this elasticity is lost at every blow. For instance, a 1 ton tup falling 20 ft., or 20 ft.-tons of energy, will produce a set of about 3 ins. in a 100 lb. rail; so also will four blows of 5 ft. each; but 20 blows of 1 ft. each, although representing the same total energy, might produce no effect at all, as the deflection produced by every blow would be within the limit of elasticity.

It is, therefore, possible to make some sort of comparison between the tests required under different specifications by dividing the total work expended by the weight of that part of the test piece which absorbs the energy. The quotient will be the number of ft.-lbs. of energy absorbed by each lb. of metal under test in producing the effect described in the specification. In comparing rails of different sections the actual deflection produced by a given expenditure of energy will be nearly in the inverse proportion to the depth of the section.

On several tramway systems of recent construction the test required was a piece of rail 5 ft. long on bearings 3 ft. apart, to stand the impact of a weight of 2,000 lbs. falling from a height of 18 ft. without flaw or fracture. On a 100 lb. rail this corresponds to an absorption of 360 ft.-lbs. of energy per lb. of metal between the two supports. Other engineers require the tup to weigh 1 ton and have a drop of 20 ft. On a 100 lb. rail this means an energy absorption of nearly 450 ft.-lbs. per lb. It is sometimes stipulated in addition that there shall be "no undue bending," or again that the deflection shall be "not less than 2 ins. nor more than 4 ins." These tests are undoubtedly very mild ones; in the case of the 101 lb. rails required for the Brighton Tramways the tup weighed 25 cwt. with a drop of 20 ft., the same limits of deflection; this corresponds to an energy absorption of 550 ft.-lbs. per lb. Another recent specification required a deflection of 3 ins. to 5 ins. under a blow from a 1 ton tup falling 18 ft. and show no signs of fracture at the second blow, which corresponds to an energy absorption of 840 ft.-lbs. per lb.

The London County Council specification—102 lb. rail, test piece 5 ft. on bearings 3 ft. 6 ins. apart—calls for a deflection of ⅞ in. to 1 in. from a 1 ton tup falling 7ft., to be followed by a second blow from a height of 20 ft. producing a deflection of 3 ins. to 4½ ins. with no signs of fracture. This is a total absorption of 510 ft.-lbs. per lb., and the overhang on the bearings is small, which would assist the specimen in bearing the test. At Manchester a rail of same weight, but on bearings 3ft. apart, had to withstand two blows of a 1 ton tup falling 15 ft., with a deflection of less than 3 ins. and no signs of fracture; here the absorption energy is at the rate of 660 ft.-lbs. per lb. In another case a 100 lb. rail has to withstand three blows from a 1 ton tup falling from heights of 10, 15, and 20 ft., corresponding to a total energy absorption of about 1,000 ft.-lbs. per lb.

The following are mean results of tests on three 100 lb. rails, 7 ins. deep; tup weighing 1 ton falling 10 ft.; test pieces 5 ft. long on 3 ft. bearings; measurements in 16ths of an inch :—

Blow.	Mean of 3 deflections.	Increment in 16ths inch.	Energy absorbed per lb.
1st	$\frac{15}{16}$	—	224
2nd	$1\frac{11}{16}$	12	448
3rd	$2\frac{5}{16}$	10	672
4th	$2\frac{15}{16}$	10	896
5th	$3\frac{5}{8}$	11	1220
6th	$4\frac{3}{16}$	9	1444
7th	$4\frac{15}{16}$	12	1676

The test pieces failed at the eighth blow, in one case by breaking, in the others by becoming so badly twisted that no measurement of the deflection could be made. The average carbon was about ·40 per cent.

The tensile strength usually specified varies from about 35 to 40 tons per square inch and elongations equivalent to 20 per cent. in 8 ins. for what are intended to be the softer kinds of steel; to 40 to 45 tons and 10 per cent. elongation for the harder kinds. The contraction in areas at the fractured surfaces are about 30 per cent. and 20 per cent. respectively. These properties of the metal vary in a somewhat indefinite way with the variations in its constituents; and they also probably depend to some extent upon the details of manufacture, such as temperature of rolling, &c. They also depend upon the dimensions of the test piece; a short one will show a high percentage of elongation because the "neck" or local contraction near the fracture forms a large proportion of the total length.

Opinions differ as to the length on which this elongation shall be measured; some engineers specify that it shall be a length of 2 ins.; others that it shall be 6 ins. and 8 ins. The last-named dimension is adopted in the American Steel Makers' Standard Specification, except when the thickness is $\frac{5}{16}$ in. or less, when it shall be 16 times the thickness; for rounds $\frac{5}{8}$ in. diameter or less the length is to be equal to 8 times the diameter of the section tested. The elongation can, of course, only be measured after bringing the fractured surfaces into contact again; the fit is never perfect, so that an error is introduced into the dimension from which the elongation is calculated, and this error is relatively of the less importance in the case of the longer test pieces. The British Standard Specification provides for a length of 2 ins.; this is a length frequently adopted by English engineers, but the chief, and perhaps the only, advantage it possesses over the longer standard is that the samples are less expensive to prepare.

Roughly speaking, and of course referring only to the class of steel from which tram rails are made, it may be said that the tensile strength varies as the amount of carbon present, and that anything below 40 tons per square inch will indicate soft metal with carbon at, or very little above, ·40 per cent. The elongation in such material will probably be over 20 per cent. and the contraction in area over 30 per cent. A "high carbon" rail, ·50 per cent. to ·55 per cent., will have a tensile strength of 48 to 50 tons or more, with an elongation of 12 per cent. to 15 per cent. and a contraction in area of about 20 per cent.

Besides the above-mentioned "tests" it is sometimes required that the heat at which the rails are rolled shall be as low as possible, so as to increase the pressure which the rolls exercise upon the metal in forcing and squeezing it into shape. It is doubtful if there is any real advantage in this low temperature of working, as although the pressure may be increased, the resistance to the closing and welding up of any incipient flaws and laminations will be increased likewise. Any hardening produced in the final passes is probably only skin deep.

The length of rails affects the economy and convenience in handling; the longer they are the greater the necessary strength of the platelaying gang who have to load up and unload them, handle them on the ground, and fix them in place. Until a very few years ago the lengths varied from 24 to 30 ft., by far the most common being 27 ft.; it was then increased to 40 and 45 ft. on one or two lines, and now lengths of 60 and even 63 ft. are not uncommon. The primary object in using these long lengths is to diminish the number of joints; this is probably the only advantage they possess, and it is offset by several disadvantages. Whatever length be chosen it should be a multiple of the tie-bar spacing, and it is usual to accept delivery of a portion, say 10 per cent. of the whole, in shorter lengths, but still some multiple of the tie-bar space. Frequently it is specified that the actual length shall be less than the nominal length by the amount allowed for expansion of the joint.

The allowance, if any, made for expansion should properly be made to depend upon the length of the rail, and also upon the temperature or season of the year. This, of course, is on the assumption is just sufficient for the gap to be completely closed when the rails are at the maximum temperature of a hot summer day. The co-efficient of expansion of steel is 0·0000065 per degree Fah.; *i.e.*, it expands that fraction of its total length for each degree rise in temperature. Assuming, then, a 30 ft. rail at the normal temperature of 60°, its increase in length for a rise to 100° will be 30 ft. × 12 ins. × 40° × 0·0000065 = 0·09 ins., or nearly one-tenth of an inch. It will, of course, be that much shorter than 30 ft. at 20° Fah., the temperature of a cold day in winter, or a total variation of one-fifth of an inch for 80° variation in temperature. In a 60 ft. rail the variation under the same conditions would be 0·4 in., or over ⅜ in.

The time when expansion is most likely to cause inconvenience is in the interval between the fixing and lining up of the rails in place and the completion of the concrete and surrounding paving. If the rails are butted up too closely at a low temperature when laid they are very apt to spring out of place under a hot sun, especially on curves. Any sensible change in temperature puts them under constraint, and the shocks and jars due to the works may afford sufficient momentary freedom to allow a movement to take place. After the paving is laid it is usual to assume that no further movement is possible; it is probably true that the movement may be too small to be readily measured, but it is certain that under some conditions or types of construction it is great enough to have a very injurious effect upon the permanent way as a whole.

CHAPTER V.

JOINTS.

IN dealing with the question of rail-joints, it will be convenient to first consider the action of a pair of ordinary fish-plates.

A girder rail freshly bedded may be supposed to have a continuous bearing upon its concrete foundation; but as the bedding soon becomes dis-continuous, the rail is supported only at isolated points, and some device for maintaining approximate continuity of the upper surface at the joints becomes necessary.

Suppose for a moment the fish-plates to be absent altogether; a rolling load advancing towards the end of rail A (fig. 21) overhanging its point of support, bends it down with a gradually increasing deflection until it rolls off on to the next rail B, which must suffer a still greater deflection since it is subjected to the dynamic action of a suddenly applied load. The actual positions of the virtual points of support do not affect the argument; there *is* a point of support somewhere on each side of the joint, but support being lacking at the joint itself deflection ensues.

It is easy to calculate the deflection at the free end of a beam fixed at one end, and loaded at the other, when all the data are known. In fig. 20 the beam fixed horizontally at C is subjected to a certain load P. The deflection produced is exactly the same as though the beam were of double the length, supported in the middle, as at D, with a load $P^1 = P$ applied at the other end. If a minute increase be made in the load P, so that P^1 is raised until the lower side of that end of the beam becomes level with the support D obviously the deflection at P will be double what it was before, even when $P^1 = P$: if P^1 be less, then the deflection caused by P will be greater still. Hence it follows that no amount of loading or anchoring down of the rail will prevent or diminish the deflection of its free end, and that deflection must be at least (and may be more than) double that due to an equal load applied in the same manner to the free end of a "fixed" beam of the same length of overhang.

If the joint be fitted with fish-plates of a rectangular section, fig. 22, no matter how close the fit may be, there will soon be *some* play with open spaces at top and bottom under a load P as shown in fig. 21. These spaces will be somewhat of the form shown, and they change instantly as the load passes from rail A to B to the form shown in fig. 23; all open spaces are closed up with a snap, any grit between the surfaces utilised in producing its proper increment of wear and tear, and other

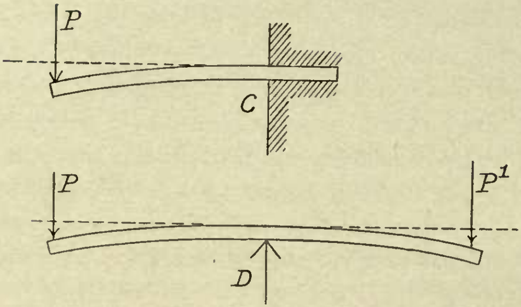


Fig. 20.

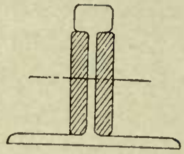


Fig. 22.

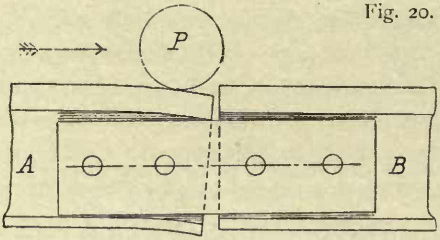


Fig. 21.

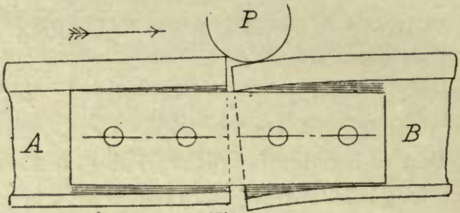


Fig. 23.

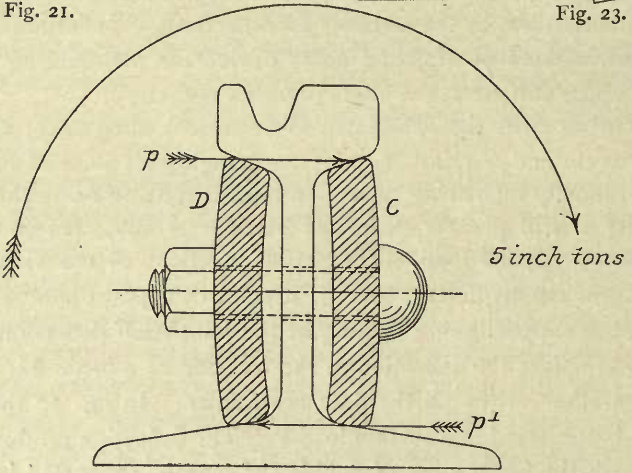


Fig. 24.

spaces opened up for the reception of such other grinding material as may find room to enter.

But the rectangular plate is not a practical form. By inclining the upper and lower surfaces sections are produced which can be easily rolled, and which will be pulled into good contact on screwing up the bolts. The best results are obtained by making these bearing surfaces flat and definite, with a moderate inclination, say something between 6° and 12°. The considerations which fix this angle may be stated thus. It is found that this is about the "angle of repose" of dry metal on metal, *i.e.*, this is the greatest angle at which a plane may be inclined to the horizontal before a body placed upon it will begin to slide down. If therefore the top of the fish-plate be inclined at a greater angle than this, pressure upon the head of the rail will tend to wedge the plates outwards. The least "give" of this sort sets up a grinding action between the surfaces, and the joint soon calls for attention.

The above is written on the assumption that the bearings under the rail, wherever they may be, are on its centre line, or else extend squarely across the foot; it is but rarely that this can be true. When the effective bearing is nearer to one edge than the other of a rail under deflection, a moment's consideration will show that the fish-plates have to withstand a *twisting* action, as well as a downward bending, and it is quite probable that this twisting may have a greater influence in pulling a joint to pieces than the vertical bending stresses hitherto dealt with.

An idea of the effects of this action may be obtained thus. Suppose a pair of plates bolted up to a rail A, and their free ends cut away so as to project only an inch beyond the end of this rail, pointing upwards from the paper in fig. 24. Suppose now the end of rail B to be inserted between the projecting ends of these plates, and subjected to a twisting moment of say 5 inch-tons, which has to be resisted by the fish-plates bolted to rail A. In a 7-inch rail this twist would cause a pressure of about 1 ton at top of fish-plate C, and an equal one at bottom edge of the fish-plate D. The outward pressure on C will set up another pressure inwards on the lower edge of that plate, and on the far side of the first bolt which acts as the fulcrum; and similarly there will be a corresponding symmetrical pressure on the inside top edge of D. It should be noticed that, *e.g.*, the pressure p, forcing over the top of fish-plate C, tends to open the joint between the top of this plate and the head of rail A to which C is bolted, and at the same time to open the joint between the bottom of C and rail B. It is not easy to show these actions in a diagram, but a moment's consideration will make them clear.

When now the wheel rolls on to the next rail A, all these forces are instantaneously reversed, surfaces in close contact are opened out, and open joints are suddenly jammed into close contact. Further, the surfaces are not brought together or separated in a normal direction, but with a sidelong slide making a very small angle to them. The fact that the relative movement between the surfaces is exceedingly small does not make much difference eventually; it gets a bit more every time a car wheel passes, and it is only a question of time and intensity of traffic for it to become large enough to be sensible.

A proper recognition of the forces which tend to pull a joint to pieces is necessary in judging of its merits, and hence the reason why they have been dealt with in some detail. The description given, however, takes no account of the effects of expansion and contraction nor of corrosion, nor of imperfect fitting and workmanship, and from the nature of the case it cannot be made quantitative or be submitted to definite calculation. The object has been to define the principal features of the problem, because without a clear conception of them the results of any particular device are likely to be imperfectly understood. It will be seen that the problem is essentially that of connecting the free ends of two indefinite cantilevers in such a way as to eliminate as far as possible the destructive effects brought into play upon these connecting pieces when the load is suddenly transferred from one cantilever to the other. The cantilevers and connections are all buried in the roadway, and anything in the nature of high class machine work and fitting is out of the question.

The principal joints in common use are illustrated by figs. 1 to 12, and it is unnecessary to deal with them all in detail. The fish-plates should have large bearing surfaces, and the pressure be distributed over them as uniformly as possible: this is best done by slightly curving the plates, so that each one acts as an arch under the pressure of the bolts, tending to flatten and spread the pressure over its abutment. The bolts tend to bend flat plates inwards, increasing the pressure upon the inside parts of the bearings, and reducing or perhaps removing it altogether from the outer parts. Badly fitting fish-plates mean excessive and irregular wear and ultimate destruction. In the Glasgow joint this tendency to bend is reduced by the zig-zag arrangement of the bolts.

The principles enunciated point to the advisability of using long fish-plates, certainly nothing less than 2 ft. in length, and when angle fish-plates are not used it is probable that double this length could be justified. The longer fish-plates would stiffen the beams in the region where the curvature begins, and so tend to diminish the droop at the end of the cantilever. Mere lengthening of the plates, however, is not enough; in a sense the longer the plates the more flexible they are; so long as they are long enough to get an adequate grip, the extra metal is better put where it will do most good, and this is as a projecting flange or wing forming the angle fish-plate illustrated by figs. 4 and 12. The pair form a strong secondary girder better fitted to withstand the vertical forces than the same amount of metal distributed in any other way possible in a fish-plate *of that depth.* The deflection is inversely as the moment of inertia of the section, and plain fish-plates of the same depth and equal stiffness as the angle plates shown in fig. 12 would have to be more than twice as thick, and 50 per cent. greater in weight. The increase in weight might be tolerated, but the increase in thickness makes them quite impracticable. The advantage such angle-shaped plates possess in resisting torsion strains is even more marked, but is not so readily formulated.

The " Victor " Joint.—

The angle plates may or may not be bolted to the bottom flange of the rail: without such bolting they are a great improvement on ordinary plates, but when they are bolted down the whole structure is stiffened and strengthened; and with the

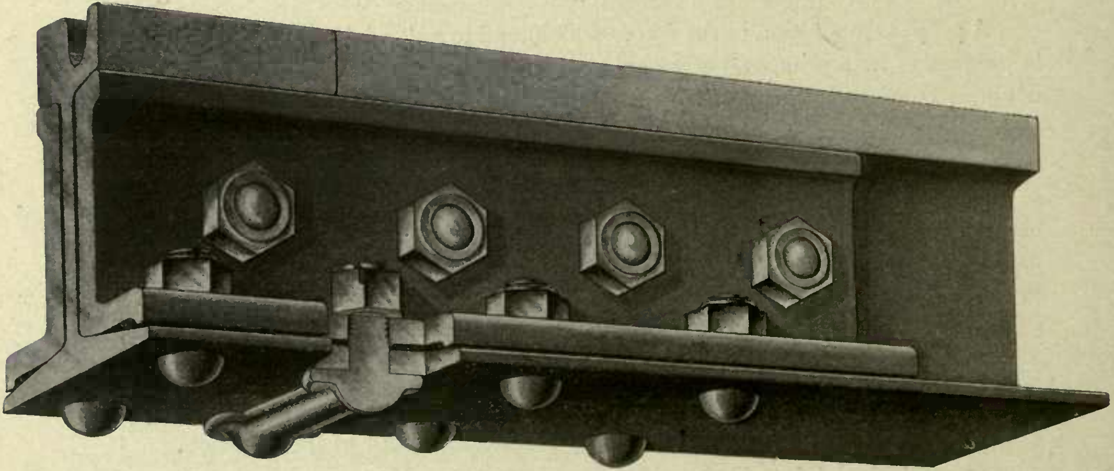


Fig. 23. The "Victor" Joint.

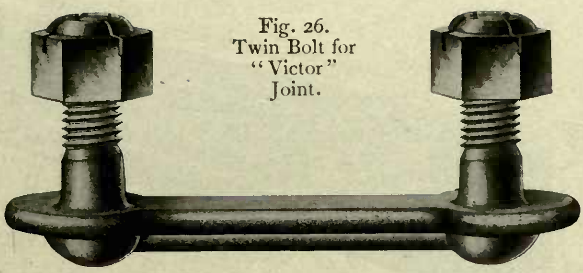
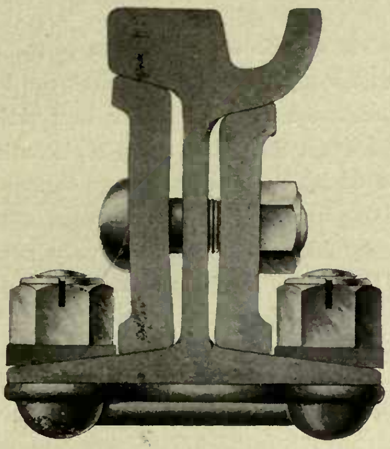
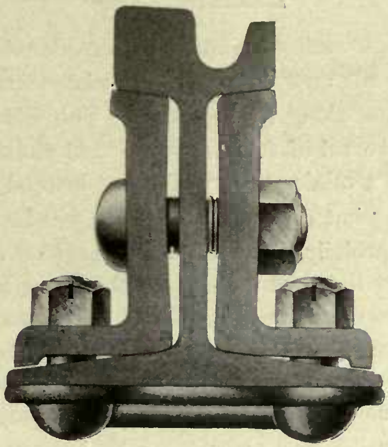


Fig. 26.
Twin Bolt for
"Victor"
Joint.



With Ordinary Fishplates.



With Angle Fishplates.

further addition of a "twin-bolt" in the middle, a very practical and efficient joint is obtained.

This combination forms the "*Victor Joint*," the various parts of which are illustrated by figs. 25 to 27. The "twin-bolt" in the middle is well placed; the extreme end of the abutting rails is the place where the relative movement is the greatest, and it is therefore the most advantageous place to put a check upon it. At any other place the bolt would be at the disadvantage of having to work against a leverage represented by its distance from the centre of the joint, but *at the centre* the movement of the abutting ends of the rails tends to shear the "twin-bolt" vertically through its centre line, and it does not seem possible to place it in a position of greater advantage. The function of the connecting web between the two shanks of this "twin-bolt" is to close up the gap at the bottom, hindering the percolation of water from the surface, and stopping its pumping action as the load passes over. This is not a small matter, but if it were, it is certain that the engineer cannot afford to discard even a small detail that tends towards the efficiency of a joint.

The "Dicker" Joint.—

In the joint shown in figs. 5 and 6 a different principle is introduced, which is perhaps illustrated more clearly by fig. 28. In ordinary plates the mischief arising from the instantaneous reversal of strains and alterations in points of pressure as the load passes from one rail to the other has been described. In this

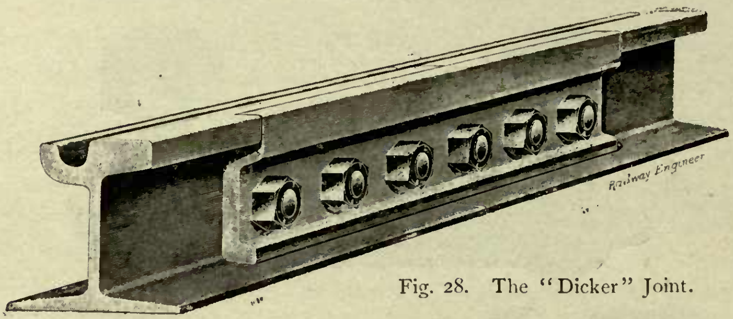


Fig. 28. The "Dicker" Joint.

joint each plate must be considered separately. It will be seen the head of the rail is cut away, and the fish-plate carried upwards through the gap so that the load runs along its top edge. This fish-plate is therefore not subjected to any violent reversal of strains as the load passes the gap between the rails; though alterations of a milder type will occur instead at each end of it, but it is not easy to specify in what degree their effects will be less than those brought to bear in other cases, especially as the bearing surface of the top shoulder is necessarily very small. On the other fish-plate they will be quite of the same kind as those previously described for the case of an ordinary plate, tempered, however, in degree by the large proportion of the load carried on the top of the principal plate. The joint is not a strong one to resist twisting strains, and it is open to the objection that it cannot be used at points, crossings, and where rails have to be cut for closures, curves, &c., since the rails have to be prepared at the mills before they are sent away. This latter objection, however, has nothing to do with its merits in the 90 per cent. or so of other instances where it can be used in the track.

The Splayed or Diagonal Joint.—

In fig. 3 is illustrated a joint which is comparatively new in tramway practice, and which, together with other details of the Hull tramways, will be watched with interest by tramway engineers. A similar joint used on railways was not attended with the results hoped for: the top bearing surface was not uniformly effective owing to the unsupported metal in the pointed end of the cut rail; but the different conditions of tramway work may give it a better chance of success. It is more expensive than a square joint, and will increase the difficulty of dealing with repairs and renewals, since the rail has to be sawn quite through at the proper angle, and cannot be cut with cold sates.

Several forms of a combination of fish-plate and sole-plate in one casting have been used with indifferent success, although in certain cases they have been an improvement on the very imperfect fish-plates they superseded. Their chief objection is that it is impossible to fit them properly; if the rail rest on the flat of the sole-plate member, the bolts pull it sideways until contact is made somewhere with the side of the fish-plate member, when further movement is, of course, stopped, whether there be then anything in the nature of a fit or not. If the head of the rail rides upon the shoulder of the fish-plate member, its foot is pulled off the sole-plate. The vertical bolts then used to complete the joint merely strain the casting, with ultimate results under traffic that need not be dwelt upon.

"Anchor" Joints.—

Various forms of "anchors" and "anchor plates" have been brought into use, with the view of fastening the rail to its concrete bed. As signs of looseness in the rail first show themselves at the joint, these "anchors" are generally placed there in any case.

"Anchoring" the joints appears to have a tendency to "hog-back" the rails, and therefore some engineers advocate the use of "anchors" at more or less frequent intervals along the whole rail length. The object in view admits of several mechanical equivalents.

Cooper and Howard-Smith's Combined Joint and Sole-Plate.—

This type is illustrated by figs. 29 and 30. The first form is that described in patent No. 23578/98, and is a length of rail inverted and bolted or rivetted to the underside of the abutting rails. The second form is described in patent No. 14941/99, and is a piece of T or channel iron, or rolled joist used in precisely the same way.

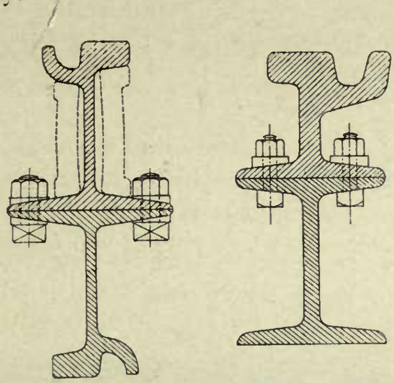


Fig. 29. Fig. 30.
Cooper & Howard-Smith Anchor Joint.

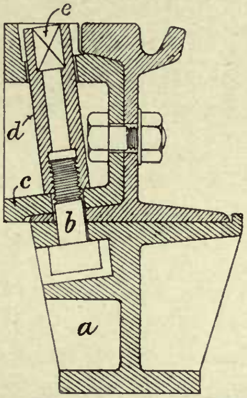


Fig. 31. Brodie's Anchor Block.

Brodie's Anchor Block.—

This anchor block (Patent No. 1267/00), shown in fig. 31, has been used to some extent upon the Liverpool tramways. It is designed for the purpose of fastening down the rails at frequent intervals. The cast iron foundation piece *a* receives the head of holding-down bolt *b*, passing into the head of a cast iron paving block *c*. This block is shaped to fit the head and foot of the rail. It is bolted to the web of the rail, and its upper surface replaces one of the ordinary paving setts. A peculiar tubular shaped nut *d* fastens this block, and with it the rail, to the foundation block *a*. Its upper end is flush with the street surface, and the hole *e* in it is there of a square shape, so that the nut and bolt can be tightened up without disturbing the street paving.

Winby's Anchor Chair.—

This is shown in fig. 32, and is also a piece of rolled joist, the upper flange being sawn off for a short distance and the free ends then turned up to form a clip for the bottom flange of the rail. As this clip must be sufficiently open to admit of the foot of the rail being placed in it, the anchor has to be fixed to the rail by a taper iron wedge in the manner shown in the figure.

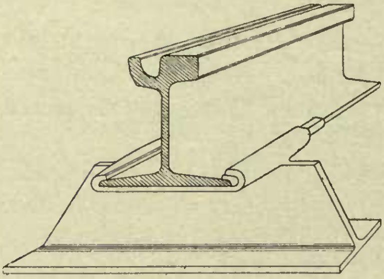


Fig. 32. Winby's Anchor Chair.

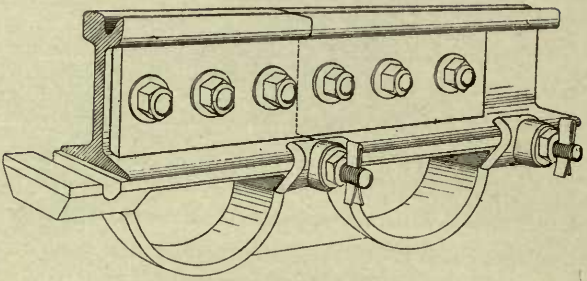


Fig. 33. Ames's Bull-dog Joint.

Ames's "Bull-dog" Joint.—

This is a cast iron anchor, as shown in fig. 33, formed with two large open loops or bows on the underside, intended to be filled with concrete so as to form part of the general mass of the foundation. The top of the casting forms a table of same width as the flange of the rail, and is secured thereto by V-shaped side clips pulled up with bolts. The bolt lies in a recess formed in the top of the casting, so that there is no drilling of the rails or special fitting necessary in fixing the anchor to the rail.

The "Wallasey" Hold-down Joint.—

This is shown in fig. 34, and is used on the Wallasey tramways. It does not depend for its efficiency upon the permanent adhesion between the concrete and the masses of metal embedded in it: the concrete acts rather as a distance piece between the rails and the anchors, so that they can be repacked and fastened down

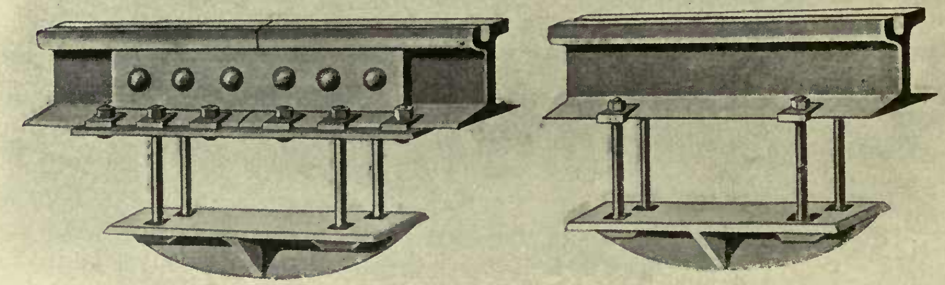


Fig. 34. "Wallasey" Hold-down Joint.

again to the concrete so long as the nuts upon the bolts are in working order. Even when these become rusted up, this anchor appears to allow of the rails being more solidly packed than is possible when there is little more than their own weight holding them down.

Binney & Sample's Rail Joint.—

Fig. 35 illustrates a method of jointing and supporting tramway rails which has been designed and patented by two members of the City Surveyor's staff of Sheffield.

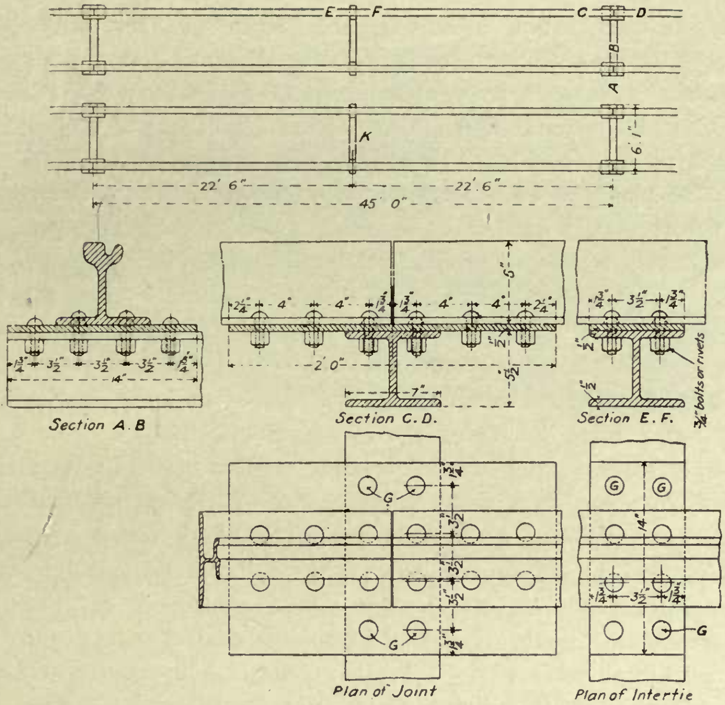


Fig. 35.—Binney & Sample's Joint.

It will be seen that the arrangement consists of a longitudinal plate riveted or bolted on to the underside of the flange of the rail, and which is in turn riveted or bolted to the top flange of a transverse H girder laid under the rails at the joints and at the middle of the lengths of the rails. The transverse girders are embedded in the concrete foundations. In double junctions and on curves where the joints do not come opposite to each other the transverse girders may be shortened, as shown at H on the plan, though the girder is carried right across the line when it is practicable to do so.

All the necessary holes in the rails, plates and girders are drilled and the sole plates riveted on the transverse girders at the works.

Anchoring Joints and Rails.—

The whole question of anchorages, whether of joints or rails, is in a very unsettled state. The bottom of the trouble appears to be that a girder rail only 7 ins. deep is not stiff enough to withstand the traffic brought upon it because its bearing upon the concrete foundation does not remain continuous. As soon as a break occurs in this bearing the rail must act as a girder across the slack place and under the passing load it deflects, prises up other parts of the same rail on the further sides of its actual bearings and sets water in motion, all of which have the effect of extending the mischief. If the rail were made 9 ins. deep instead of 7 ins.—the weight per yard remaining the same—its moment of inertia would be doubled and its deflection under any given conditions reduced by one-half: the disintegration of the surrounding paving would thereby be postponed and would increase at a much slower rate and consequently the cost of repairs and maintenance would be substantially reduced. But increasing the depth of the rail would raise questions as to the best way of dealing with the standard 4 ins., 5 ins., or 6 ins. pavements, and endeavours have been made to avoid them by anchoring the shallower rail to its concrete bed. The rail is only a part of the whole track: every effort is made to eliminate the joints in it, and to make it as continuous and uniform as possible, and from the very nature of things the control of a metallic structure of this kind, submitted to the action of heavy rapidly moving loads, must present a difficult mechanical problem for solution. Engineers may claim to have successfully dealt with it on railways, and if the rails only were concerned the railway experiences would go far towards a settlement of the question. The difficulties, however, are met with in the roadway in which the rails are placed; pavements of all kinds are sooner or later shaken loose, and involve very heavy costs in keeping them in repair.

Really effective anchoring would certainly tend to check the vibration which causes the mischief, but there seems small chance of it being permanently accomplished on the present lines. Most of the devices that have been or are now on trial aim at making a rigid attachment between the rail and the concrete at more or less frequent intervals. At every point where control is exercised steel and concrete surfaces are together under pressure, for control of one over the other can be exercised in no other way. Vibration means a hammer-like action between these two surfaces, and the ultimate result must be the disintegration of one of them until the pressure is released and control destroyed. For a time the anchors may act as buttresses, or as nodes on a vibrating string, and cause any tendency to movement which would otherwise be spread indefinitely along the whole length of the rail to be concentrated on the parts between the anchors. Some kind of anchor, or of attachment to the rail, may be discovered which will meet the difficulty; but in any case the rigid attachment of rail to concrete is unmechanical and not consistent with the known properties of cement as used in concrete and paving works.

Sole-Plates.—

The very problematical effects of anchoring are not involved in the use of the plates of iron or steel placed under the ends of rails and bolted up to the foot and which have been very extensively used to strengthen an ordinary fish-plate joint.

The objection to sole plates wider than the foot of the rails is that it is almost impossible to pack them evenly. The stuff rammed under them will be harder on one side than under the other, so that the bearing will not be uniform, and the twist thus brought upon the joint precludes all hope of permanent stability.

Askham's Sole-Plate.—

The best known form is that introduced many years ago by Messrs. Askham Bros. & Wilson, of Sheffield, and illustrated in fig. 36. It requires no detailed description, but it may be remarked that whereas its standard thickness used to be ½ in., on some tramways of recent construction the thickness has been increased to ¾ in. and even 1 in.

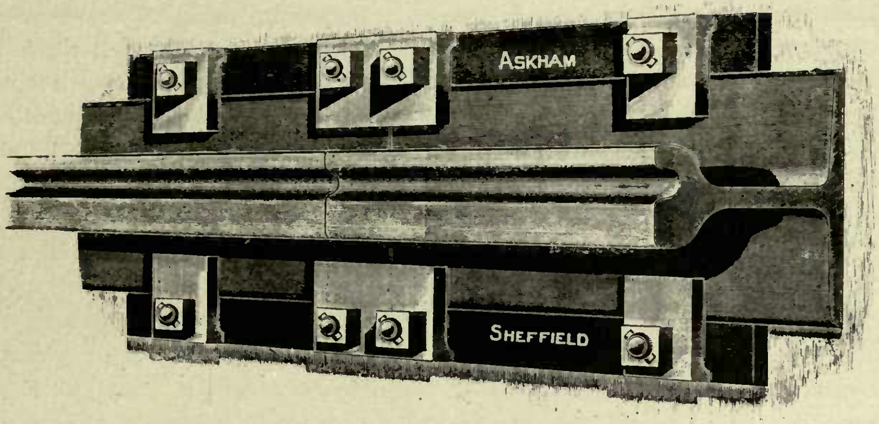
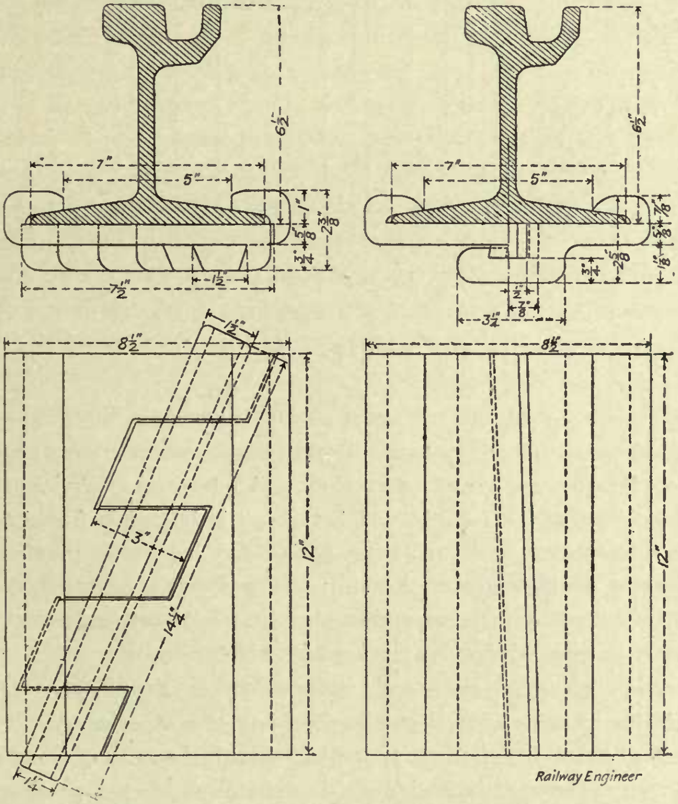


Fig. 36.—Askham's Sole Plate.

Hadfield's Sole-Plate.—

Figs. 37 and 38 show two forms of a cast steel sole-plate introduced by Hadfield's Steel Foundry Co., Ltd., of Sheffield, and intended to reinforce a joint formed with ordinary fish-plates. No bolts are used, but instead thereof the two halves are formed with hook-like projections jointing below the foot of the rail;



Railway Engineer

Fig. 37. Hadfield's Sole Plate. Fig. 38.

a taper steel wedge driven in between the opposing faces of these hooked projections clamps the two parts of the plate into contact with the rail, in the manner clearly shown on the drawing. The form shown in fig. 1 is probably the better of the two, as the two halves of the plate are nearly duplicates of each other, and the wedge being driven in obliquely is more readily fixed in place than when it has to be fixed along the centre line.

Estler's Sole-Plate.—

Fig. 39 illustrates a sole-plate proposed by Messrs. Estler Bros., which acts

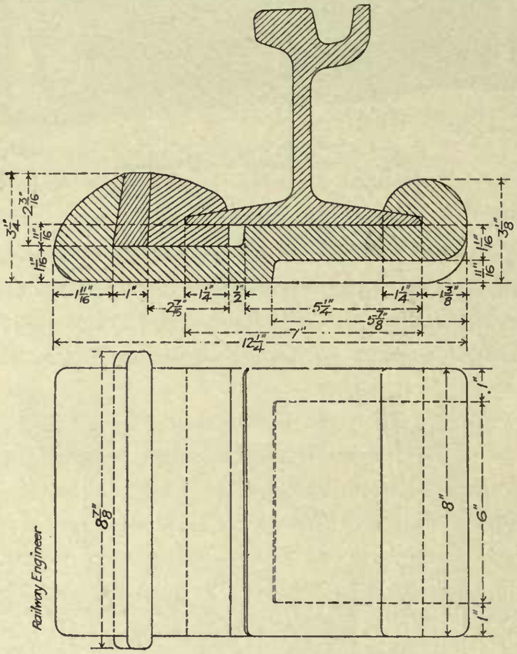


Fig. 39. Estler's Sole-Plate.

in very much the same way; the closing wedge in this case being on the upper side of the casting is therefore readily fixed in place.

Eliminating Joints.—

The arguments in favour of some means which will eliminate the joint altogether are obvious. Such methods would have been used long ago on railways if it were not for the effects of expansion and contraction: on a tramway the conditions are different; the road in which the rail is buried is found to be capable of resisting any tendency to deformation which may be set up by them. The rail takes the average temperature of the soil; changes in that temperature are slow, and the usual result of expansion and contraction is to set up a certain strain in the metal which in general does not exceed its elastic limit.

The question of expansion and contraction is the most important one. Advocates of the welded joint prove easily that the stresses due to this cause cannot exceed a small fraction (say one-fourth) of the ultimate strength of the metal; and to show how completely this is controlled by the pavement in which the rails are bedded, give as an instance that when fracture from contraction does take place, in no instance has the gap produced in the rail exceeded 2 ins. wide. The combined openings due to several fractures in a line of rails 3 miles long did not exceed 6 ins., whereas the aggregate contraction due to that length was about 8 ft. 6ins. Hence it follows that the grip of the surrounding pavement on the rails, tie-bars, &c., is sufficient to prevent the contraction made possible by a fracture in the rail extending more than a very moderate distance each way.

These fractures are a very small proportion of the welds made, and something more than the bare effects of contraction is necessary to explain them, as may be shown thus :—The co-efficient of expansion of steel is 0·0000065 per ° Fah., *i.e.*, the metal expands or contracts that fraction of its length for 1° variation. The maximum of climatic changes, so far as the rails are concerned, is about 80°, so that the climatic co-efficient will be 80 × 0·0000065, say 0·0005. When the fracture has produced a gap of 2 ins. each end has pulled back 1 in., and the shortest length of rail that would give that contraction is obviously 1 ÷ 0·0005 = 2,000 ins., or 166 ft. It is quite improbable that the length concerned is much, if any, greater than this; because any movement at all on the part of the rail can only take place when it has torn itself free of its surroundings, and then there is nothing to prevent the contraction exhausting itself. Hence it is highly improbable that there is anything in the nature of a tapering away of this contraction to any extent beyond the 166 ft. mentioned.

Then as to the magnitude of the force due to contraction. Molesworth gives the modulus of elasticity of steel as 29,000,000 to 42,000,000. It is probable that the modulus of hard tramway rails is somewhere about 36,000,000, *i.e.*, a strain 1 lb. per square inch would elongate a bar 1-36,000,000th part of its length; or for 1 ton the elongation would be 2,240 ÷ 36,000,000 = 0·00006. To produce an elongation equal to ·0005, *i.e.*, sufficient to stretch the 166 ft. bar back to its original length, obviously only 8·33 tons would be required, or only about ⅓ more than would be allowed for a working strain on such metal in ordinary structural works. The actual tensile strength of the steel which has been pulled asunder by this force is probably 35 to 40 tons per square inch. But the bar has been broken by a stress which is only one-fourth of this amount.

The most likely explanation is that the fracture started with some incipient flaw or crack, which would cause a concentration of the force around it. The stress in the bar adjacent to the crack must obviously be greater than elsewhere, since none of the force can be transmitted across it. If then the elastic limit be exceeded in front of the crack advancing across the bar, it must extend with every repetition of the stress, and complete fracture ultimately take place. What the total stress really is at this point cannot be computed, for besides the 8 tons or so due to contraction, we have the stresses due to the rail acting as a girder (of unknown length of bearing) under passing loads : in addition to these we have the effects of vibration, intensified by a frozen road-bed, producing severe momentary strains, all tending together to cause the crack to spread across the metal; ultimately producing fracture under a tension which the bar could probably carry with safety when distributed over the whole section. In a homogeneous metal such as steel

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a minute flaw may extend in any direction in a manner quite impossible in a material of definite fibrous nature.

There is no doubt also that the effects of "fatigue" or the effect of varying stresses frequently applied should be taken into consideration. Wohler's experiments showed that a bar could be broken by a stress very much below its "breaking stress" if it were applied a sufficient number of times; and if this stress were alternately tensile and compressive it would be considerably less than half the normal breaking stress. It is impossible to specify the effect of these various factors, but, bearing them in mind, there does not appear to be anything mysterious about the fractures in the rail.

Welded Joints.—

There are three distinct welding processes in use which call for description, viz., electric welding, cast welding, and aluminium welding.

Electric Welding.—

As applied to tramway joints electric welding must not be confounded with the process so extensively boomed a few years ago, and which was expected to revolutionise in so many ways the arts of working in metals. Strictly speaking, the abutting rails are not welded together, but each of them is welded to one or more pieces of metal applied to each side of the rails and covering the gap between them. The ends of the rails are brought close together, or else the gap is filled up with a thin "shim" or slip of the shape of the rail section. The rails are then cleaned for a space of two or three inches on each side of the joint by means of an emery wheel; pieces of steel or lugs are then applied on each side to the polished surfaces, and a current of electricity passed through them from one to the other, of sufficient volume to raise the lugs and the parts of the rails between them to a welding heat. Pressure is then applied to the lugs and the whole blended into one mass.

The lugs are so shaped that the smallest part of their section is in contact with the rails; this, and the resistance due to the surface of contact, causes the heat developed by the current to be localised, and, of course, the rise in temperature causes a still further resistance at the place where the desired weld has to be formed.

In order to keep down the volume of the current necessary, the lugs are applied in two pairs, the lower pair reaching only about half way up the web of the rails. When this pair has been welded the second pair is applied, but out of contact with the lower pair, and the process is repeated.

In some of the most recent work carried out on this principle the separate lugs have been abandoned, and instead thereof a kind of fish-plate has been used. The plate has on one side a boss with a projection of about ¼ in. extending transversely across it in the centre, and a smaller pear-shaped boss at each end. A pair of such plates are applied to the joint, the bosses covering the gap between the rails and the current passed through them as before, the whole being squeezed into welding contact when the proper temperature has been obtained. The centre joint being completed, the ends of the fish-plates are secured by welding the smaller bosses to the rails in the same manner. To get a current of the volume required, the ordinary tramway service current at 500 volts is transformed by a motor generator into an alternating current at about 300 volts; this again is transformed by a static transformer into the alternating current of 3 or 4 volts, and a volume of something like 30,000 or 40,000 ampères which is required to effect the actual welding. The apparatus is therefore excessively cumbersome and costly. If the tramway current be not available, a perambulating steam engine and generating plant is necessary, and there is not much saved in bulk and cost even when the 500 volt current can be drawn upon. There is no doubt this is the reason why the process has not been more extensively employed.

Cast Welding.—

This process in conception at any rate is a very old one, and English patents date at least as far back as 1851. There was no use for it, however, until the protection and restraint afforded by the street paving made it possible to apply the process to connecting the rails of a tramway. The rail ends are cleaned by an emery wheel or a sand blast; they are then enclosed in an iron mould, and the space around them filled in with molten cast iron of a "special" mixture, given by one authority as 25 per cent. scrap, 25 per cent. soft, and 50 per cent. hard silicon pig. The molten metal makes a more or less perfect union with the surface of the steel rails, but authorities differ as to whether this union is perfect enough to form a satisfactory electric joint. There would, however, appear to be no room for doubt that it makes an efficient mechanical joint not lacking in strength, rigidity, or accuracy of fitting. The apparatus, however, is again cumbersome and costly, it is not fit for jobbing work, and it does not pay to use it until there is a good stretch of tramway already laid upon which it can be brought into operation. The objections that have been raised in some quarters to the use of a portable cupola and welding furnace in the public streets have little weight, as the apparatus is necessarily perambulatory and cannot stop long in one place.

The Goldschmidt or Aluminium or "Thermit" Welding Process.—

This process may be applied in two distinct forms; the one first used was a true welding of the rails together, end-on; the abutting ends are raised to a welding heat and then pressed together until the union is complete. This is rendered possible by the intense heat developed by the oxidation of aluminium in its metallic form; the oxygen being obtained from oxide of iron, which is mixed with the aluminium in a granulated or more or less finely divided state. The chemistry of the process is all contained in the formula

$$2\,Al + Fe_2O_3 = Al_2O_3 + 2\,Fe.$$

The aluminium and oxide of iron mixture (to which the name "thermit" has been given) is caused to unite in a convenient crucible; the resulting mixture of alumina and metallic iron is at once the source of the heat and the vehicle for conveying it to the rails to be welded, the iron constituent of the mixture not being utilised in any other way in forming the weld.

The rails, after being laid and lined up in place, are brought close up together

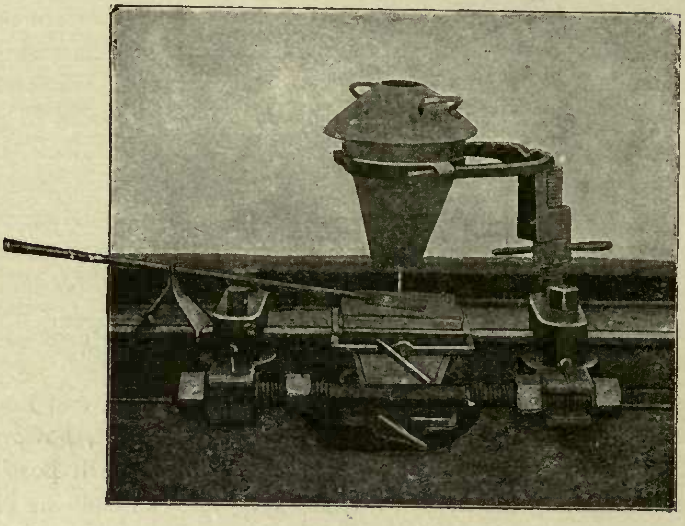


Fig. 40.—Thermit Welding.

and on each is fixed a peculiar clamp 10 or 12 ins. away from the joint, the clamps are then connected together by a strong bolt on each side. Thin sheet iron moulds of a capacity sufficient to receive the quantity of molten mixture necessary to raise the rails to the required heat are then placed on each side of the joint, and packed up outside with ordinary founders' sand. The molten mixture is then poured into the moulds in the same way as the cast iron in the previously described process. The first contact of the liquid mixture with the cold rail and sheet iron mould solidifies a thin skin of the alumina slag, thus protecting the metallic surfaces, and the heat of the remaining mass raises the ends of the embedded rails to a proper welding heat. A turn or two on the nuts of the long bolts connecting the two clamps before described squeezes the abutting rail ends together and the weld is complete. When the rails have cooled down, the clamps, sand and sheet iron moulds are removed, and the solidified mass on each side of the rail knocked away and the work is finished. Any bulging on the top of the rail caused by the pressure upon the softened metal is ground away by an emery wheel or otherwise removed. This arrangement of the apparatus is illustrated by fig. 40.

There is, however, one respect in which it differs from the others which must be referred to. The end-on pressure between the abutting rails can be applied only when one of them is free. In new tramway works this can be arranged for by working steadily in one direction, and closing up the pavement behind as the welding is completed. In tramways already laid it can only be obtained by taking up the paving to an extent sufficient to set free the whole of the rails, working onwards, say, from one joint to the next.

In the second method to which reference has been made, there is no necessity for the rails to be free, and the operation produces a "cast weld" in many respects similar to those formed by molten cast iron in the older process. A pair of sheet iron moulds are clamped to the rails, the refractory material lining them being so shaped as to form a cavity round and under the rails, enclosing in its centre the gap between them, and ending on one side at the top in a funnel shaped opening. The proper quantity of "thermit" required for one operation, about 22 lbs. for a 100 lb. rail, is placed in a sheet iron hopper carried on a tripod immediately over the opening into the mould, as illustrated by fig. 40A. This hopper is also furnished with a funnel shaped refractory lining, the small opening through the bottom being closed by an iron bar which is removed when the combustion is complete by means of the iron lever shown in the figure. When the action is over the contents of the hopper are a mass of molten soft iron at the bottom and a layer of much lighter corrundun slag on the top. The iron plug referred to is then displaced, the molten iron passes into the cavity enclosing the joint, partially fusing the ends of the rails, welding itself to them, and making what appears to be a perfect union, electrically and mechanically.

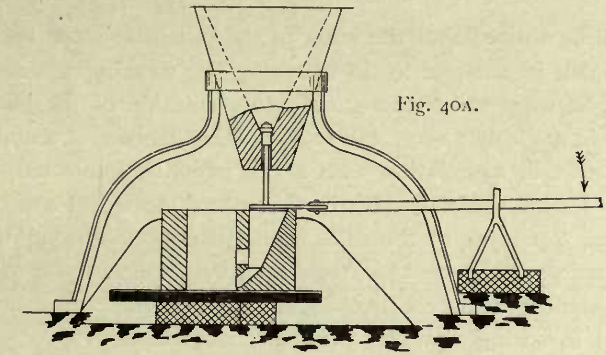


Fig. 40A.

The details of the moulds are illustrated by fig. 40B and the joint complete by

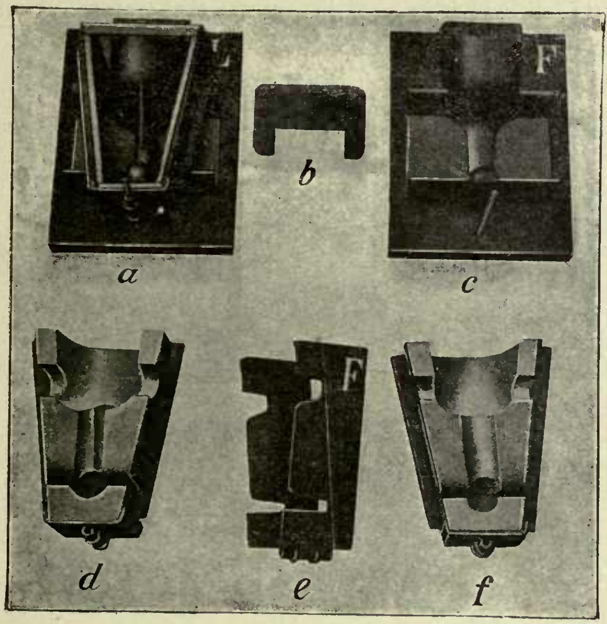


Fig 40B. Moulds for Thermit Welding.

a. Box on Running Head Side of Rail, with Pattern of Thermit-Iron.

b. Iron Plate for closing the Box while same is being filled with sand.

c. Pattern of Thermit-Iron on Check Side of Rail.

d. Finished Mould for Running Head Side.

e. Box or Frame for Running Head Side

Finished Mould for Check Side.

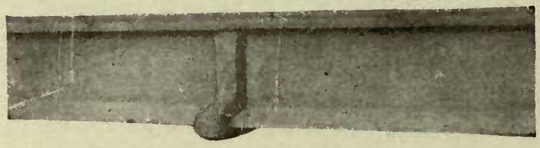


Fig. 40C.—Thermit Welded Joint.

fig. 40C. It will be noticed that the mass of thermit iron is not brought up to the top of the rail head, in order to avoid softening the wearing surface.

It must not be supposed that a satisfactory solution of the joint difficulty, be it by welding or in any other way, will remove the difficulty of maintaining a wood or granite pavement in association with a rail which is subjected to the frequent traffic of heavily loaded vehicles. In the first place the wheel traffic has the effect of *rolling out* the top layer of the rails, and thereby elongating it. An old rail is always more or less "hog-backed," and long before it is worn away so much as to be discarded, the curvature must obviously have the effect of causing the central parts of the rail to spring upwards off their concrete bed.

Again, the flexibility of the rail as a whole is not interfered with by the removal of the local points of weakness due to defective joints. The continuous rails cannot be permanently maintained in continuous contact with the foundation. The top rolling above referred to is not the only influence at work. The changes of temperature may be insufficient to strain the metals, and yet be sufficient on roads not perfectly straight vertically and horizontally to strain the pavement, and set up a movement amongst its parts. When this tendency once exists the disintegrating effect of the vibrations due to heavy loads in rapid motion must have their destructive effects greatly enhanced, and it is quite likely that the continuous rails may even assist in spreading these effects.

CHAPTER VI.

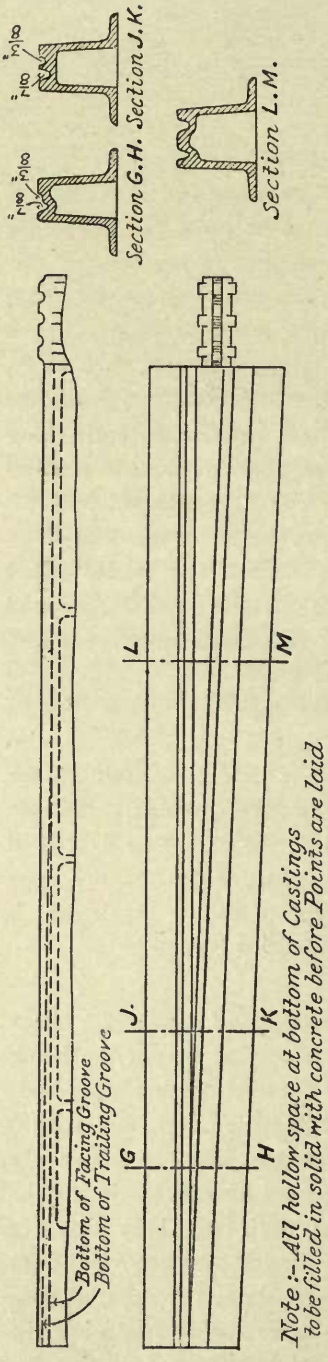
POINTS.

THE conditions expected to be fulfilled by a point in a street tramway are exacting. As far as possible the groove must be kept intact on both roads, hence the long gradual merging of one line into the other, which is quite characteristic of railway work, cannot be obtained. Two grooves an inch wide can be made to approach each other as gradually as may be desired, so long as there is a rib of metal between them, but when this tapers away to nothing, the groove becomes two inches wide: this is too great for safety in a public street, and must therefore be shortened and tapered away to the normal width of one inch as quickly as is reasonably consistent with the smooth working of the traffic.

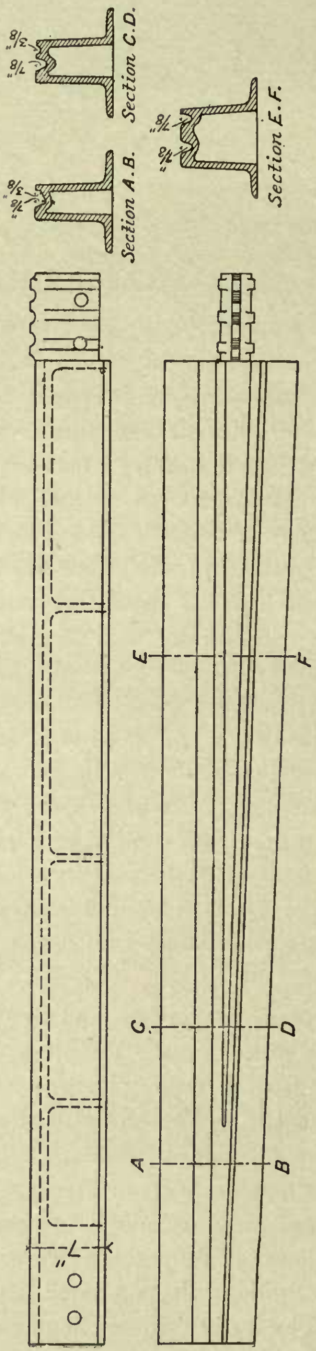
A consideration of this problem raises indirectly the question of the type of cars to be used on the tramway and the speed at which they are to be run: a point that is quite suitable for bogie cars run at a low speed may be quite unsuitable for cars with a fixed wheel base run at a higher speed. The latter named conditions will tend to prevail in the future, but it may be useful to consider first a type of point that has served all purposes in the past in a fairly satisfactory manner upon lines worked under Board of Trade rules and with a type of rolling stock that is now fast passing out of date, viz., bogie cars drawn by steam locomotives.

"*Drop-off*" *Points.*—

Figs. 41 and 42 show plans, elevations, and cross-sections of a pair of "drop-off" points. They are for girder rails 7 ins. deep, 3 ins. wide across the head, with groove ⅞ in. wide and ⅞ in. deep. Each point is a steel casting with body 7 ft. 6 ins. long, formed to the exact section of the rail at one end, and with a projecting boss at the heel forming a packing or distance piece to which the adjacent rails are bolted. Chipping fillets or fitting strips are formed on the cheeks of this boss, and are trimmed away as may be necessary until two short pieces of rail being bolted up to the boss fall properly in line with the top and grooves of the casting. A fin about ½ in. wide projects a small distance above the rails, closing the gap between them, and by its broken or chequered upper surface reducing the trouble likely to arise from a large area of smooth metal in the roadway. The hollow shell of the casting is of ½ in. thickness of metal, with three transverse stiffening ribs, the whole weighing about 5 cwt. Such in general terms is a


Section G.H.
Section J.K.
Section L.M.
G
H
J.
K
L
M
Bottom of Facing Groove
Bottom of Trailing Groove
Note :- All hollow space at bottom of Castings to be filled in solid with concrete before Points are laid

41. Left Hand Point.



42. Right Hand Point.

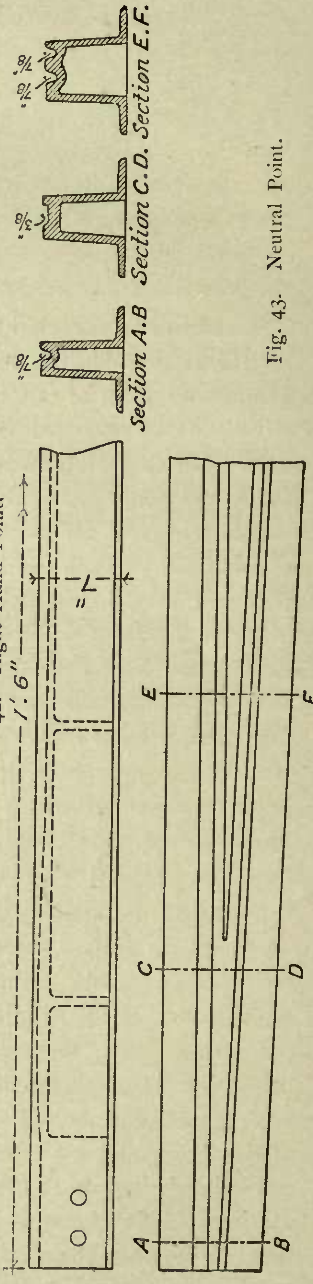


Fig. 43. Neutral Point.

description of not only the points illustrated by figs. 41 and 42, but of the great majority of solid points (*i.e.*, points with no moveable parts) used on street tramways. The metal used is either ordinary cast steel or manganese steel (the special properties of which will be dealt with later), and for light traffic chilled cast iron has been used, but this material is by no means economical under mechanical traction of any kind.

To deal with the shape in detail, the most essential feature is the form and disposition of the grooves. The points are called "right" or "left" hand according to whether they lie on the right or left hand when viewed in the road from the "toe" towards the "heel." In England a car going in this direction always takes the left hand groove, in well marked contrast to American and Continental practice.

To insure the car taking the proper road, it will be seen from the cross-sections on figs. 41 and 43 that the "trailing" groove in the right hand point is filled up to within ⅜ in. of the top throughout the space in advance of the "frog," while the "facing" groove is of full depth throughout. In the left hand point this filling up is more partial, the step shown on the section A B being bevelled away to the full depth of the facing groove.

The "drop-off" pattern has been strongly condemned in many quarters as being noisy in action and destructive to the rolling stock. These are weighty reasons, and against them it is said that the point is cheap and the step soon gets cut away by the wheel flanges, so that the noise and destruction are lessened in a great degree. In truth these statements are more in the nature of excuses rather than reasons for adopting such a type of point; a thing that is cheap is rarely economical, and never necessarily so, and if the step causing the "drop-off" soon wears away and the point is not thereby rendered useless, the reasons for introducing it in the first instance appear to be inadequate.

Neutral Points.—

Hence the use in many cases, and in suitable situations with satisfactory results, of either the "open" point with both grooves of the full depth throughout, or of the "neutral" point with both grooves partially filled up in front of the frog. The Author prefers the "neutral" point, as shown in fig. 43; it is true that the wheel flanges soon cut away the grooves to the depth of the average flange, but the wear and tear on the "tread" is saved at least until this has been done, and it is saved also wherever wheels having flanges of greater than the average depth pass through the point. In the aggregate these savings are substantial and form quite a sufficient reason for the selection.

Mention has been made of "suitable situations" in which these points may be used. This detail of situation does not always receive proper attention. It is more a question of platelaying than of point construction, but the best of points may be rendered inefficient by clumsy workmanship in laying them, and so also may skilful workmanship sometimes make cheap and simple points thoroughly efficient in working. Apart from "junctions," the function of a point is to deflect the wheels of a car into the left hand groove, and the best way of ensuring that the wheels will take this course is to so lay the points that the left hand groove shall be in the line of the rails leading up to it. This is quite necessary in the solid points that have been described, and it is also a great help in the working of the mechanical points yet to be dealt with.

It will be noticed in fig. 41 that the two grooves meet at the end of the point or toe; this has the effect of causing the flanges of the wheels passing through the point in the trailing direction to strike the edge of the groove in the rail about six inches in front of the toe and to there wear away a notable hollow, especially when ·30 to ·35 carbon rails were used. To avoid this damage to the rails the grooves may be made to meet 9 ins. behind the toe of the point, and all local wear is thus confined to the casting itself, which has to be renewed several times over during the life of the rail. With harder rails, ·50 to ·60 of carbon, the effect is very slight and may be neglected.

The great objection to these solid points is the risk of cars taking the wrong road by getting a bias or a lurch to the wrong side when passing through the open space common to the two grooves. This may be due to irregular wear of the wheels or axle boxes, or to some casual obstacle in the groove. In the points shown, the divergence being 3½ ins. in a length of 7 ft. 6 ins., the length of this diverging space with a 1 in. groove is about 25 ins.; practically it is nearly 3 ft., because the frog or fin between the two grooves cannot be tapered away to a sharp point. The danger of cars taking the wrong road under these circumstances is the greater the less the length of the fixed wheel base of the car; with a long wheel base the rear wheels have a greater steering power so to speak, and greater power to prevent the front wheels making any sudden divergence from the straight. Hence there is a much greater risk of the short truck of a bogie car with a wheel base of 3 ft. 6 ins. or 4 ft. taking the wrong road than there is with an engine whose wheel base is 5 ft. or 5 ft. 6 ins.

Kenway's Swell Point.—

The most obvious way of shortening the length of this open space, and of thereby diminishing the risk alluded to, is to partially close up the trailing groove as at K in fig. 44, which is part plan of Kenway's "swell point." The length of open space may be reduced about one-third in this way without seriously deforming the groove. Unfortunately the projection K is gradually worn away, and if provision is made against this by making it too prominent, it causes an objectionable lurch to vehicles passing through the point in the trailing direction, and the greater the speed the greater is the lurch so experienced. Used as a facing point this trouble is not met with, as there is no projection upon the line of the left hand groove.

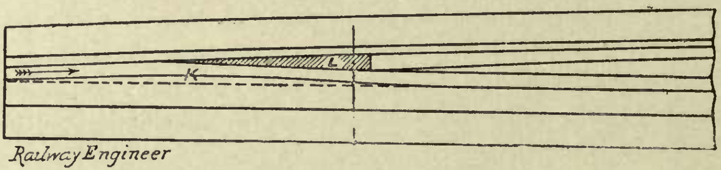


Fig. 44. Kenway's "Swell Point."

The shaded portion marked L is a recess in the bottom of the groove into which a steel wedge may be dropped for deflecting a car into the right hand groove upon emergency.

The safety of all these solid points depends very largely upon rigid compliance with that regulation made by the Board of Trade, limiting the speed through facing points to 4 miles an hour. Instructions to drivers are not always observed, and it is necessary in the great majority of cases to lessen the risk of facing points by fitting them with moveable tongues, which shall freely admit the passage of cars in the trailing direction through the point but automatically close this groove entirely to a car coming in the other direction.

Automatic Points.—

From what has been said it is clear that all forms of solid points possess the inherent defect of leaving the trailing groove open to a car coming in the facing direction, and that there is nothing to prevent a wheel taking the wrong groove at a passing place, except its tendency to travel on in the same straight line, and such controlling influence as the wheels behind it may possess. This may be sufficient in some cases, but in others it is quite necessary to close the groove by a moveable piece or tongue capable of being easily moved aside by a wheel in the trailing groove, and automatically closing that groove to a wheel coming in the opposite direction. It may be advisable to describe a few of the many different ways that have been adopted for accomplishing that object.

Amongst the earliest of the automatic points were Chapman's and Winby's patents; it is believed that these points have quite gone out of use, but they are referred to for the purpose of pointing out two serious defects; both quite unexpected and only revealed by practical experience.

Chapman's and Winby's Points.—

Fig. 45 is a sketch of one form of Chapman's point. The tongue *a* filled the front end of the trailing groove, moving vertically in an elongated hole in the bed of the casting, and pivotted on a horizontal pin *e* at the back end; its left hand edge defined the facing groove, being flush with the top of the point as far as the frog, and dropping towards the back end to the full depth of the groove. The front end could rise or fall, but had no lateral movement. Two plans were tried to raise the tongue after it had been depressed by a passing car. In the one shown by fig. 45 the lever *b c* carries a vertical piece *d* projecting about ½ in. above the head of the rail when the tongue is depressed; a wheel rolling over it raised the toe of the tongue, thus closing the trailing groove. The other plan was more effective; the end *c* of the lever carried a heavy counterweight; in Winby's patent this loaded lever was replaced by a spring, but in other respects the points were practically identical.

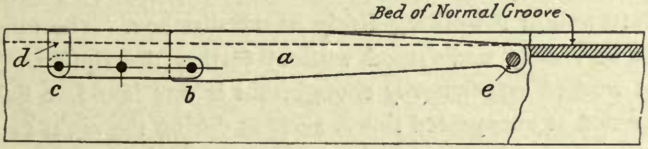


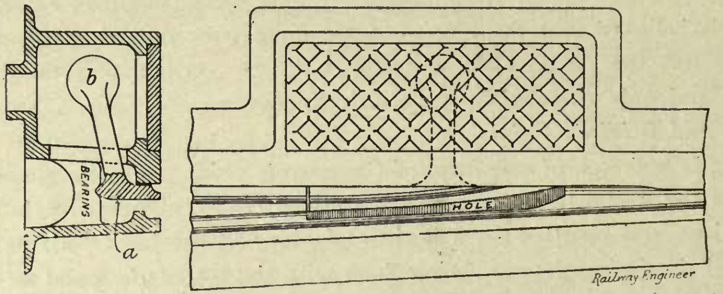
Fig. 45. Chapman's Point.

It was found that the edge of the recess in which the tongue worked soon became burred or rivetted over by the passing wheels, thus preventing the tongue rising freely, and besides the vertical slot on each side of the tongue was particularly apt to get choked with mud or dust. It was also clear that the closing of the trailing groove was more apparent than real, even when the tongue did rise again to its proper level. The least side pressure of the flange of a wheel in the facing groove was sufficient to depress the tongue against any spring or counterweight. As a wheel rolls, the parts of the rim about to come into contact with the rail are moving *vertically downwards*, and so also are the adjacent parts of the flange; thus the edge of the tongue was not called upon to deflect a piece of metal sliding horizontally along the groove, but to stand up against a bevelled piece moving vertically downwards upon it. No spring or weight could be depended upon to keep the moveable tongue in the required position; the trailing groove was virtually left open, and it seems obvious that this defect will be fatal in any attempt to close the groove by a vertical moving piece.

Phillips' Patent Point.—

This point is illustrated by fig. 46.

The trailing groove is closed by a peculiar shaped piece *a*, about 3 ins. deep, fixed in an opening through the bed of the point-casting, the groove is continued for a short distance in its upper surface and bevelled off, upwards and sideways, disappearing entirely before the other groove is reached. The lower side of this piece works on a bearing formed in the main casting, and an extension sideways forms the counterweight *b* working freely in the dirt box. The other features of the device will be readily understood without further description. While it was clean the point worked satisfactorily enough, but it was found so liable to become choked and jammed at unexpected times, such as during the night or in the winter, that it was given up.



Railway Engineer

Fig. 46. Phillips' Patent Point.

Dickinson's Patent Point.—

Fig. 47 shows Dickinson's patent "short tongue" arrangement.

The tongue *a* is a shallow steel forging, of an inverted ⊤ shape, bearing on the upper surfaces of two or three ribs of the casting *b*, which is bolted to the underside of the main casting. It will be seen from the figures that this end of the casting is enlarged and chambered out underneath to give room for the flat parts of the inverted ⊤-shaped tongue to work into, and this is carried by the ribs of *b* at

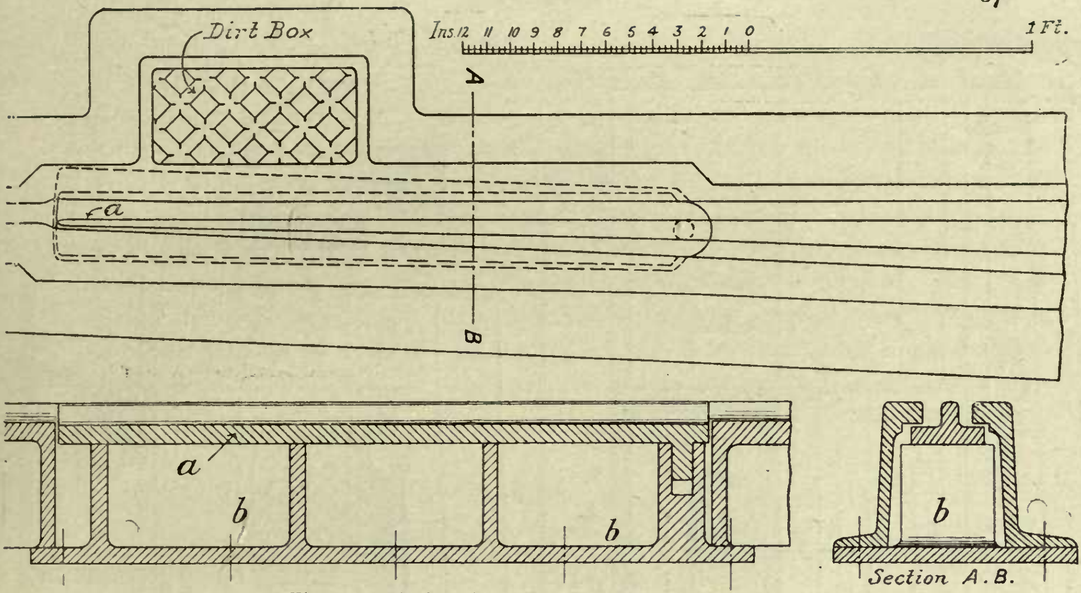


Fig. 47. Dickinson's "Short Tongue" Moveable Point.

such a level that there is no appreciable gap anywhere on the upper side to admit dust or dirt. A spiral spring, not shown in the figures, always keeps this tongue over so as to close the trailing groove when an automatic point is required: if this spring be omitted, the point may be used as an ordinary moveable.

Kincaid's Patent Point.—

Fig. 48 shows the essential features of this point, which is still in use on certain tramways.

The tongue *a* is a heavy triangular casting, considerably thicker at the bottom than at the top. Its triangular shape throws the point of support at the heel very near to the top surface of the point, whereas at the toe its supporting point is about 12 ins. below the surface, *b* is a horizontal pin rigidly fixed to the tongue and projecting into the dirt box, *c* is a similar pin projecting from the wall of that

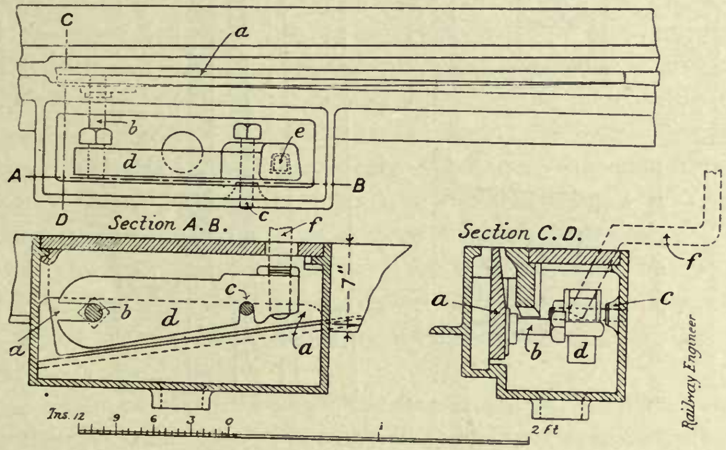


Fig. 48. Kincaid's Point.

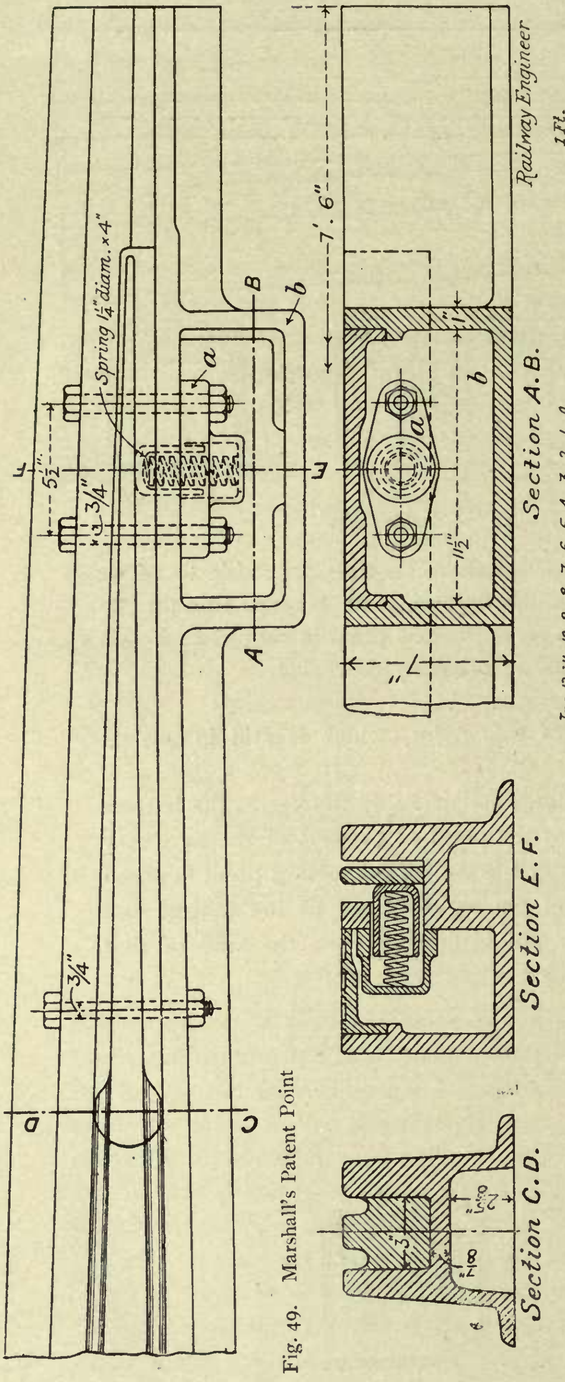


Fig. 49. Marshall's Patent Point

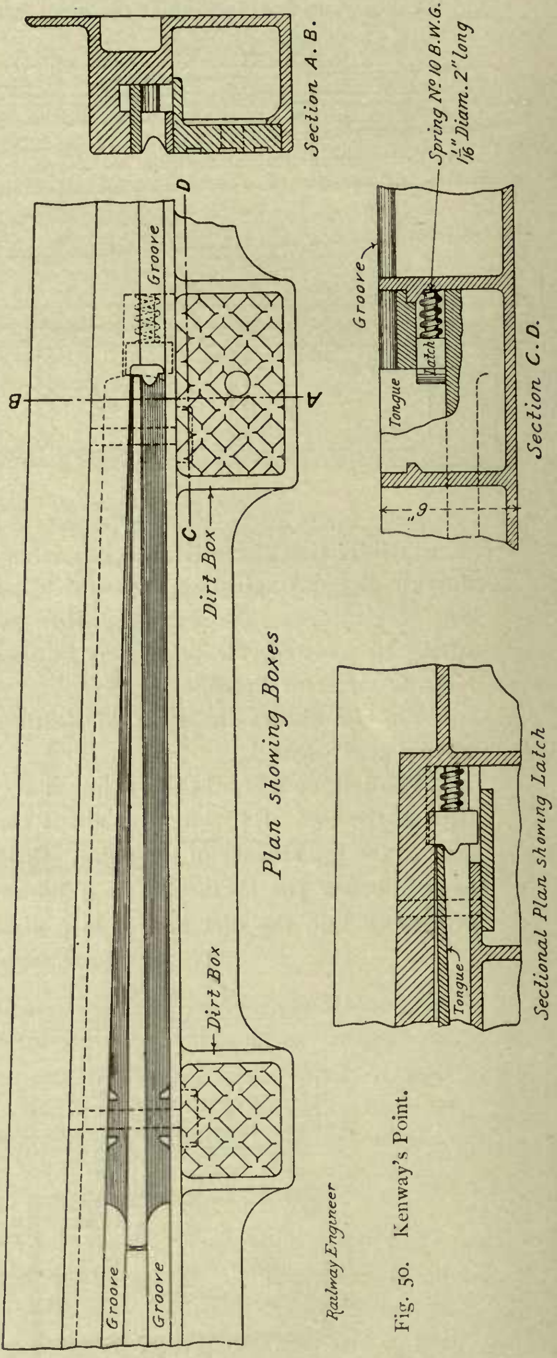


Fig. 50. Kenway's Point.

box, *d* is a counterweight pivoted on *c*, and bearing at the front end on the pin *b*: its effect is to keep the tongue over to the right, effectually closing the trailing groove to an advancing wheel, but giving quite sufficient freedom to a wheel going in the other direction, *e* is a hole in the weight into which a bar *f* can be inserted through a slot in the dirt box cover, enabling the tongue to be thrown over to the other side, if required to act in the opposite direction; the bar *f* is cranked to clear the overhanging parts of the passing car, as the weight must obviously be held up while the car is passing through the point in this reverse direction. The other details about this point need not be referred to, as it is not much used, though it has done good service: it is essential to keep it clean, and to have the dirt box well drained and deep enough to afford a free escape for any road detritus that may get into the pocket in which the tongue works.

Marshall's Patent Point.—

The construction of this point must be pretty generally known, as large numbers of them have been used on tramways in all parts of the country. It is illustrated by fig. 49.

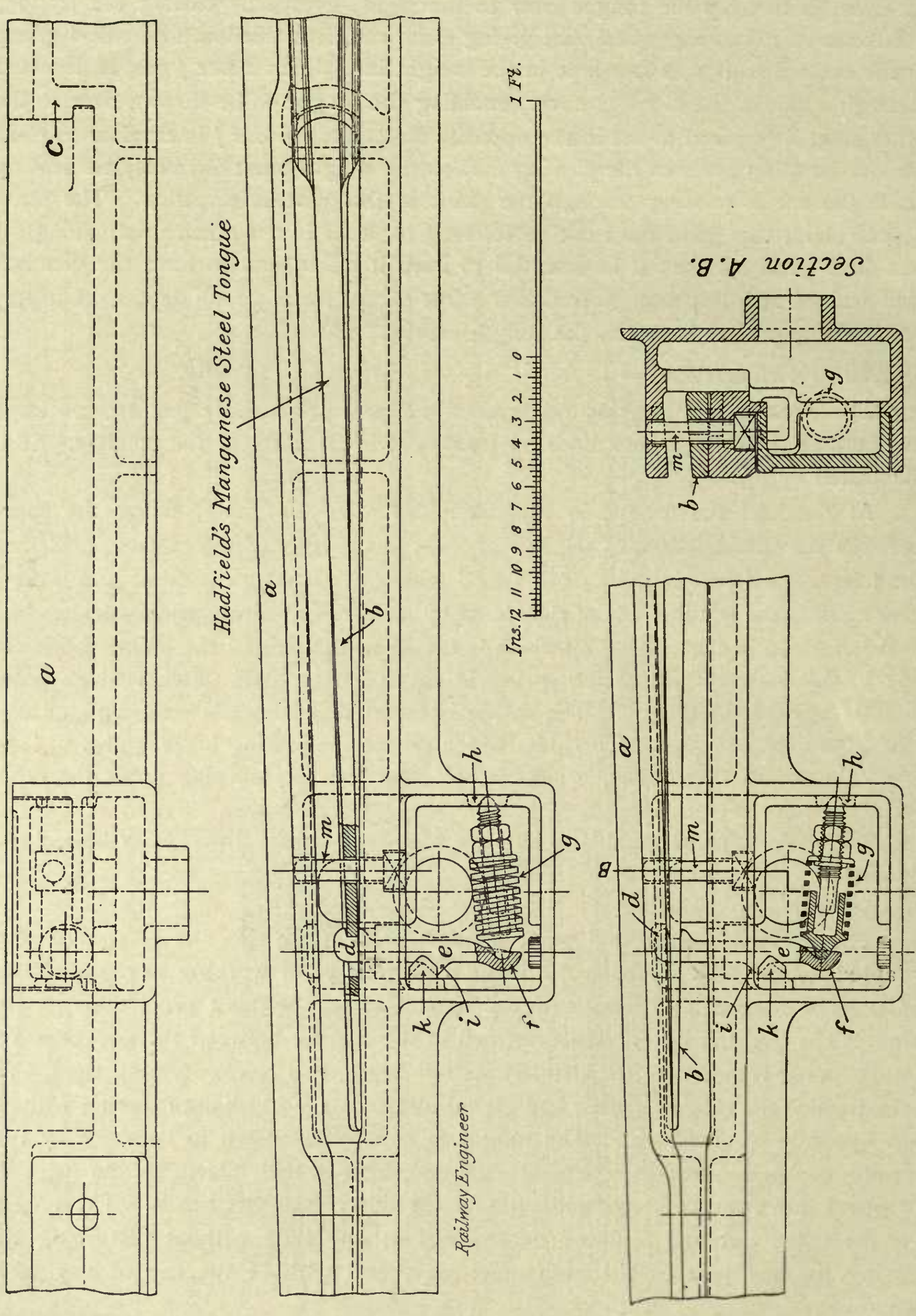
At the heel the tongue is expanded into a circular boss, filling the space between the outside edges of the two grooves in the body of the casting, centering the tongue, and forming the pivot round which it works. The front end is kept over against the trailing side of the recess by means of a spiral spring working in a pocket formed in the casting *a*, which is bolted to the side of the point, inside the box *b*, the outward end of the spring is covered by a steel thimble which bears directly against the tongue. The spring is therefore completely enclosed and kept free from dust and mud. The bolts which secure the casting *a* serve also to keep down the toe of the tongue, a similar bolt near the heel keeping down the other end.

The makers of Marshall's points are Messrs. Askham Bros. & Wilson, Ltd., Sheffield.

Kenway's Patent Point.—

The construction of this point is illustrated by fig. 50. It is equally well adapted for use as a moveable, or as an automatic point working in one direction only. The tongue is a plain wedge-shaped steel bar, without projections of any kind. The heel fits into a recess formed in the casting between the two grooves, thus clipping it sideways for virtually its full depth, this recess forming the socket round which the tongue works, and giving all necessary freedom of motion without any specially formed pivot. The tongue is kept firmly down to its work by two unscrewed horizontal pins, one near each end, kept in their places by the specially designed downward projecting flanges of the lids of the dirt boxes. The tongue can be taken out and replaced or renewed at any time without disturbing the paving, or any part of the permanent way, and without the use of any tools whatever.

When used as a moveable point, the tongue is kept over to the one side or the other by a spring latch, fitted in a recess in front of the toe, and opening sideways into the dirt box: it is kept outwards by a spiral spring bearing on the back of the


c
a
Hadfield's Manganese Steel Tongue
a
b
m
d
e
i
k
f
g
h
1 Ft.
Ins. 12 11 10 9 8 7 6 5 4 3 2 1 0
Section A.B.
g
m
b
a
B
A
d
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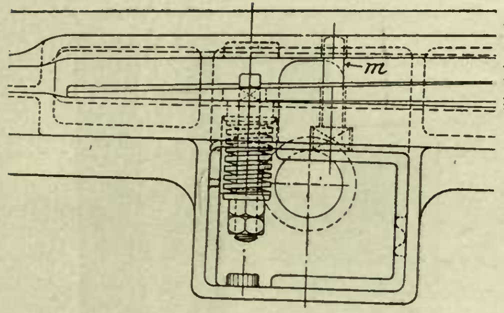
Railway Engineer

Fig. 51. Hadfield & Brown's Moveable Point.



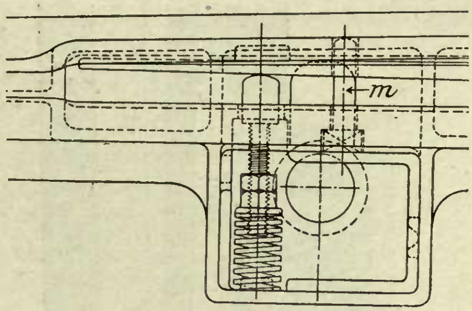


Fig. 52. Automatic Pulling Point. Hadfield & Brown's Point. Fig. 53. Automatic Pushing Point.

recess, its V-shaped head being formed at such an angle as to admit of the tongue being thrown over to the one side or the other by an ordinary point bar, and yet holding it firmly in position when so thrown over. When the point is required as an automatic the latch is removed and the tongue kept over to its proper side, either by a block of india-rubber pressed into the recess alongside the tongue near the toe, or else by a metal piece fixed into one of the dove-tailed recesses shown near the dirt box at the heel. In this latter case the elasticity of the tongue affords quite sufficient freedom for the passage of a wheel in the trailing direction, but the rubber block is in general to be preferred because it throws less strain on the tongue, and never fails suddenly at unexpected times. The rubber cannot break itself, or cause anything else to fail: in certain situations where exposed to the drainage of greasy water, it becomes rotten after a few weeks, but it fails slowly, and is renewed in a couple of minutes.

The makers of this point are F. H. Lloyd & Co., Ltd., James Bridge, Staffordshire.

Hadfield and Brown's Patent Point.—

This point is illustrated by figs. 51-53.

The tongue *b* is circular in shape at the heel, and is machine ground to fit into a hole bored in the body of the casting, and is kept down by a projection *c* at the back fitting into a recess in the casting *a*. When the point is used as a moveable one, fig. 51, the tongue is held in position by the mechanism shown on the drawings. A short lever *e* is notched at one end, *d*, to grasp the tongue, and its other end, *f*, bears against a spring *g* which is supported by the side of the dirt box at *h*. The lever has a V -shaped projection *i* on it, and as the point is forced over, this projection rides over a similarly shaped projection *k* on the side of the dirt box. The spring is readily adjustable by means of nuts, and being supported at each end in cup-shaped bearings is, as is clear from the illustrations, quite free to move.

When the point is required to be automatic, the spring is turned round in the dirt box, and readily arranged to work the tongue automatically by either pulling, fig. 52, or pushing, fig. 53. In the form shown in fig. 52 a bolt with a T-head and a square neck is put through the tongue and turned round before the tension is put on the spring. No screwed bolts are used to secure the tongue, and the one

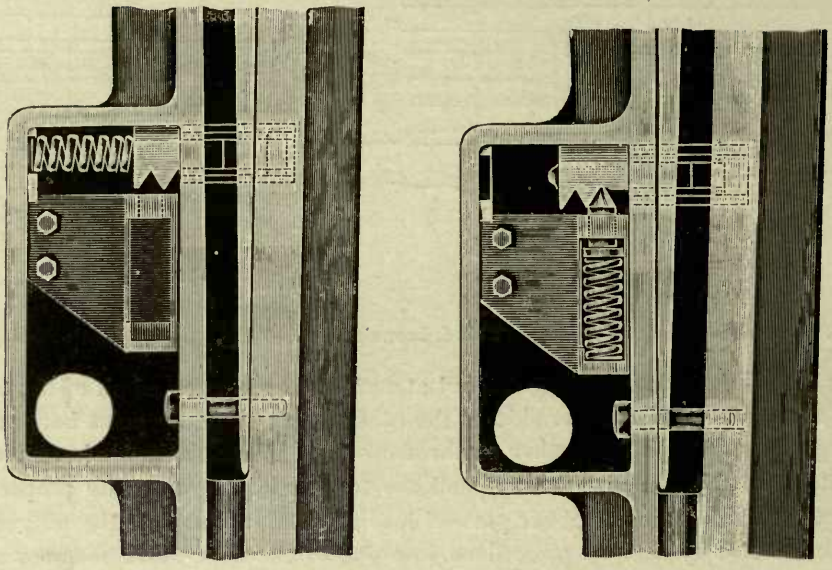


Fig. 54. Askham's Combined Automatic and Moveable Point.

pin *m* used for that purpose is held in its place by the flange of the dirt box lid. The tongue is made of " Era " manganese steel, and can be removed without disturbing any other part of the roadway. The main casting is of cast steel as usual.

The makers of this point are Hadfield's Steel Foundry Co., Ltd., Sheffield.

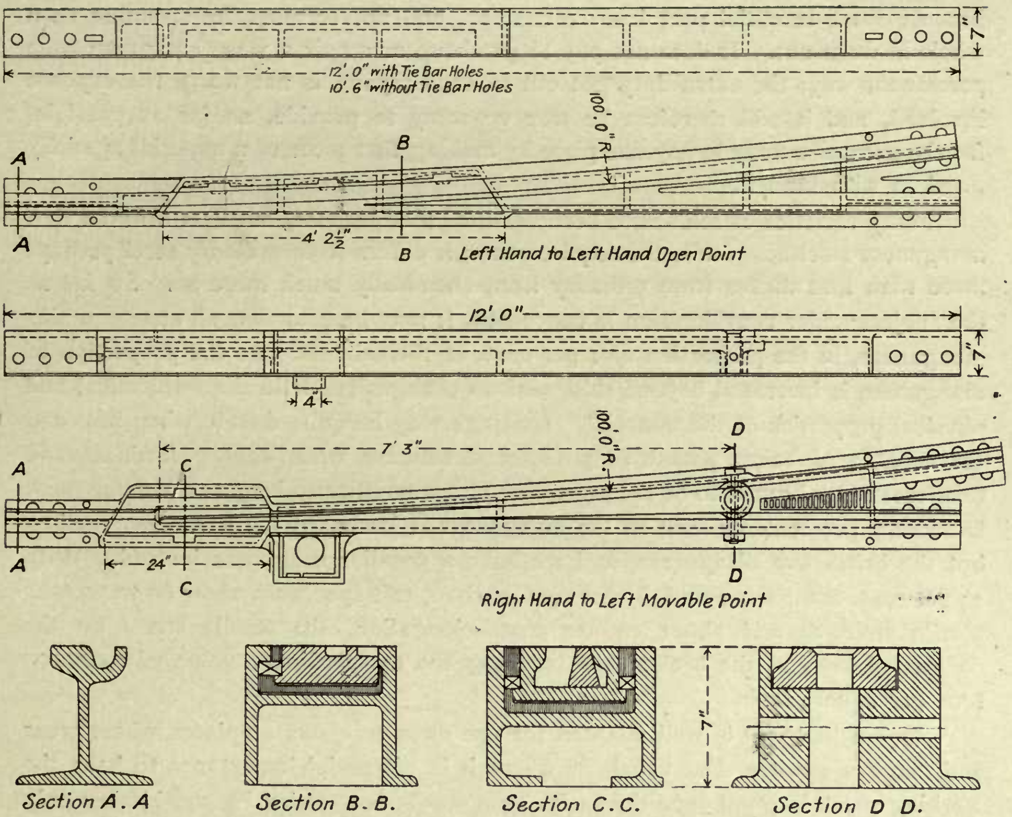
Askham's Combined "Automatic and Moveable" Point.—

This point, which is illustrated by figs. 54 and 55, effects the same purposes as the others previously described, for its mechanism is a " mechanical equivalent " of theirs. The arrangements for using this point either as an " automatic," fig. 54, or as a " moveable," fig. 55, are sufficiently clear from the illustrations without any further description than to say it is only necessary to move the position of the spring.

The makers of this point are Askham Bros. & Wilson, Ltd., Sheffield.

Long Curved Points.—

Most of the points illustrated above are 7 ft. 6 ins. long and straight throughout on both roads. For steam and horse traction these have been so generally used that they may be said to have become the standard practice. With electric traction the conditions are so much more exacting in many ways that such points are not generally suitable. They are defective both because they are short and also because the branch road starts off at a definite angle, instead of merging imperceptibly into the straight. Being short two or three joints or places of weakness are brought very close together, and it is expensive to keep them in proper running order. At the heel of the points the abutting rails must have a long taper piece cut off; their bearing surfaces are reduced where they are most required, and, besides, the fishing and bolting up of the rail to a casting is never so good a job as an ordinary joint in the normal track. With a longer point the



Left Hand to Left Hand Open Point

Right Hand to Left Movable Point

Section A. A Section B-B. Section C.C. Section D D.

Fig. 56. Long Curved Points.

increased length greatly improves the stability of the casting, the flanges of the abutting rails need not be cut away, and it is possible to make a properly fished and bolted joint.

Fig. 56 shows a pair of points of Messrs. Hadfield's make, 12 ft. long, and which illustrates these remarks.

One road through the point is curved to a radius of 100 ft., and as this is on the left hand side, the points are suitable for use on a cross-over in a double line. For a passing place on a single line the curved road must necessarily be on the right hand side. An ordinary straight point of the older pattern could of course be used in either situation.

These points show an insertion piece of manganese steel in the parts subjected to most wear. It is no cheaper in first cost than making the whole point of this material, but whether it is the most economical in the long run will depend upon circumstances too indefinite to be here stated. Other examples of these insertion pieces will be found mentioned elsewhere.

The use of manganese steel for points, crossings, and other parts of the track subject to specially hard wear is a notable feature in the more recent work of tramway construction. Points, &c., generally have to be taken out and replaced because some essential part has worn away, and not because the structure as a whole is worn out. It does not pay to patch up or repair a worn out part of the permanent way; the extra duty got out of such repairs is not worth the expense involved, and it will therefore be true economy to provide, as far as possible, for the excessive wear in any one piece by making that piece of a material specially fitted to withstand it.

Many varieties of steel have been used for this purpose, but it is believed that manganese steel best fulfils the requirements; it differs from ordinary steel perhaps more than that differs from ordinary iron, chemically much more so. So far as the subject under consideration is concerned, it may be said that all steel contains manganese, in the proportion of 1 per cent. or thereabouts. As the proportion of manganese is increased beyond this, curious changes result in the mechanical and physical properties of the material. Castings may be quite ductile when hot, and yet capable of being pounded up under a hammer when cold. Hardness and brittleness may be said to be the prevailing characteristics so long as the manganese is about 7 per cent. or less; as the manganese is increased the hardness remains, but the brittleness disappears, and we have a peculiar toughness instead. With 14 per cent. manganese and ·85 per cent. carbon, test specimens show 60 to 70 tons tensile strength and about 50 per cent. elongation, the tensile stress on the contracted area of the broken bar reaching the extraordinary value of over 100 tons per square inch.

Such a material is well adapted for use on a tramway at places where wear and tear are greater than usual, or where it is of special importance to keep the working parts in good condition. Its economy is not settled by considering only the first cost of the casting. The cost of handling, fixing in place, restoring the roadway, &c., must be added and the total divided by the "life" of the part in question. If then other things, such as safety, comfort and reliability in working, wear and tear of rolling stock, &c., are equal, the value of the fraction so found may be taken as a guide in the question of economy: where the parts are subject to heavy wear, and are expensive to replace, its value will generally be conclusive.

The effect of curving the groove, lying at an angle with the main line in which the point is set, will be, in general, to ease the passage of a wheel through the point. In a straight point the wheel has to be laterally displaced through a distance of about 3½ ins. during the time taken to traverse a length of 7 ft. 6 ins., and it is obvious that the shock to the car and its contents will be less if this displacement begins imperceptibly and gradually increases to a maximum, than it will be if the deflection begins suddenly and proceeds uniformly through the given space. In a crude sort of way, it may be said that the curvature has an effect similar to what would follow interposing a spring between the car and the force that would be necessary to bring about the given displacement in the given time.

In designing a curved point it will be found necessary to make a recess in each side of the casting to receive the toe of the moveable tongue. The tongue cannot be tapered away to a fine point; in practice it is not advisable to make it less than half an inch in thickness, and by finishing the actual point with a short definite wedge, at an angle of 20° to 25°, no appreciable obstruction is offered to an advancing wheel when the lateral depth of the recess is only half the thickness of the tongue. This will be seen from fig. 57, which shows, half size, the arrangement in a point of American manufacture. The tongue is ¾ in. thick near the point, groove in front 1⅛ in., and a recess ⅜ in. deep on each side of the casting allows the passage of a wheel through the point in either direction without sensible shock.

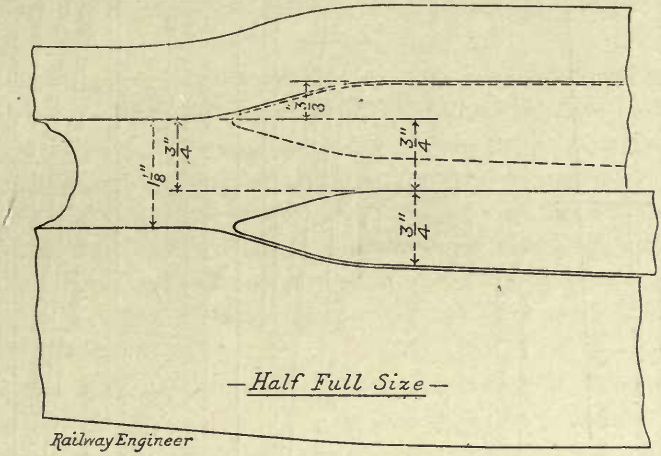
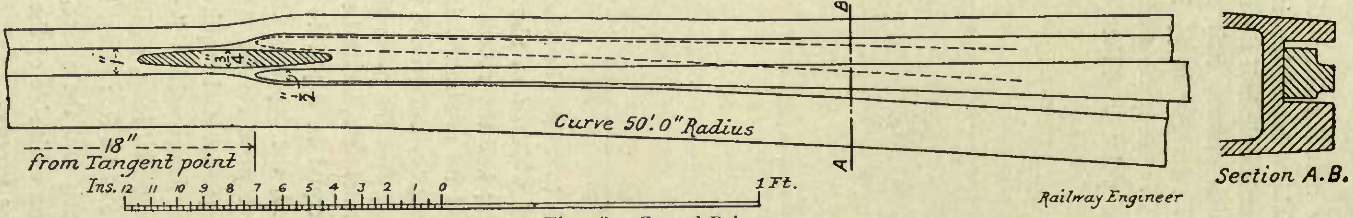


Fig. 57.

There is no necessity to make the recess deep enough to shield the whole width of the tongue when the groove in front is of the normal width, *i.e.*, about ½ in. more than the maximum thickness of the wheel flanges; but the recess *must* be deep enough to afford a free passage to the flange, and its minimum depth will depend upon the relation between the thickness of the tongue, the groove in front, and the thickness of the flange. If this be taken at ¾ in., then the minimum width of groove will be ¾ in., and the tongue, whatever its thickness, must be entirely shielded by the recess, and which must therefore be equal in depth to the full thickness of the tongue. If the front groove be widened, the depth of the recess may be reduced. The proportions shown in fig. 57 give good results, the depth of recess being half the thickness of the tongue. The one essential requirement is that there shall be a free passage for that part of the flange which lies in the groove. This is a shuttle shaped piece of metal, 8 ins. or 9 ins. long, as illustrated in fig. 58, which shows plan of a point laid out to a curve of 60 ft. radius, its exact shape and size depending upon the diameter of the wheel, and the shape, &c., of its flange. Room for its free passage must be provided on each side of the tongue, as though it were a solid piece of metal sliding along the groove.

It is evident that the least possible width for the gap in which the tongue works is the thickness of this piece of metal, plus twice the thickness of the tongue.

It will be seen that the effect of curving one of the roads through the point tends to reduce the thickness of the tongue towards its free end, and to increase its



Railway Engineer

Fig. 58. Curved Points.

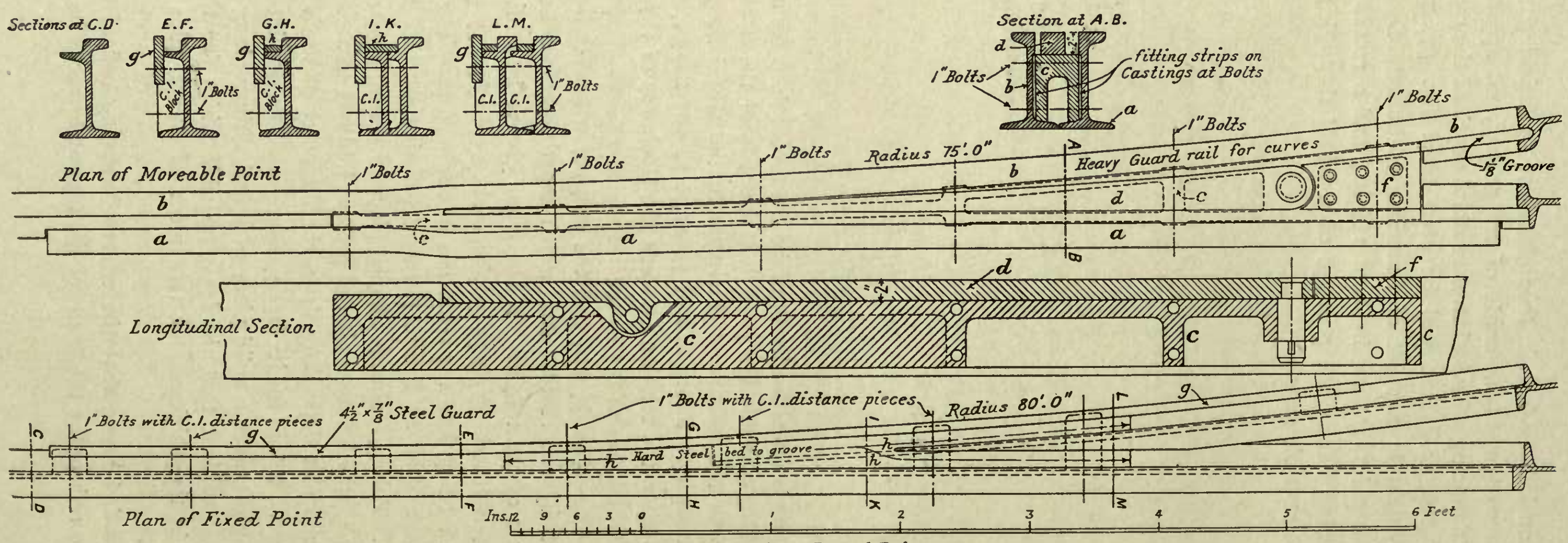


Fig. 59. American Curved Points

thickness, or breadth, at the other end. For some distance the tongue is sensibly parallel, and it is necessary to prevent it bending under the lateral pressure required to deflect a car. This is best provided for by so shaping the recesses in the casting that they act as side bearings for the tongue. Another way of preventing bending under the side strains is to stiffen the tongue by widening out at the base, as shown in fig. 58 (Section A.B.). Making projections on the sides of the casting at this lower level would not have the same effect, as they would not be of any use until the tongue was actually in contact with them, whereas the extra metal in the tongue is of some effect without any support from the side bearings.

Curved points are easily made shorter than is possible when both grooves are straight; the curved line "gets away" quicker at the heel: all depends upon the radius and position of the tangent point. When the point of tangent is placed at the toe of the point, a radius of 100 ft. will give a divergence of about 3½ ins. at a distance of 7 ft. 6 ins. To make a shorter point than this will therefore require a radius of less than 100 ft., and it will be found that a radius of 60 ft. will give one of the most generally useful points for cramped situations. This point may be made 5 ft. 6 ins. in length, and will work very easily into any practical radius of less than 60 ft.

It is evident that the points must be longer than 7 ft. 6 ins. if a radius of greater than 100 ft. is required. It will be found that a radius of 150 ft. will require a length of 9 ft. 3 ins., and 200 ft. a length of 10 ft. 9 ins.*

A good example of a pair of composite points is shown in fig. 59, the rail being the 9 ins. step or "tram" rail still largely used in America. In forming the moveable point, a piece of rail marked *a*, about 12 ft. long, has the step or "tram" cut away and turned round so as to face the curved rail *b*, which also has the greater part of its tram cut away. Both rails are cranked about ⅝ in. to form a recess for shielding the free end of the tongue. A cast iron packing or distance piece *c* separates these two rails, its upper surface entirely closing the space between them and forming a bearing for carrying the moveable steel tongue *d*; a steel block *f* forming a shield at the heel of the tongue. The other essential details of the structure are evident from the drawing.

In forming the fixed point the web of the curved rail is brought down to about the middle of the point, near the cross section G H. The other rail is carried intact straight through. It will be seen that the flat "tram" of both rails is cut away in an irregular manner as necessary; on the edge to receive the steel guard *g*, and on the flat to form a bearing for the hard tool steel plate *h*, fastened to the tram by countersunk rivets and forming a bed to the groove in front of and around the frog. The upper surface of this plate is about ⅝ in. below the tread of the rails, so that the wheel flanges take a bearing upon it in passing through the point.

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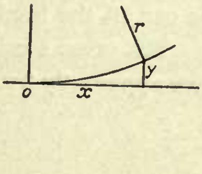
* If x be the distance from the tangent point o, y the offset to the curve at that distance, and r the radius, we have $y = \frac{x^2}{2r}$ so long as x is small compared with r.



The pieces of rail are kept to their proper lines and distances by an arrangement of cast iron blocks and bolts in a manner clearly shown upon the drawings.

Coupled Moveable Points.—

The two tongues are connected together by a transverse bar, as illustrated by fig. 60, and are shifted by a hand lever fitting into an extension of the same bar. The spiral spring shown in the transverse section always tends to keep the tongues over to the one side; the hand lever is only required when, as facing points, they are required to deflect a car into the other groove. It is necessary to keep these coupled points in very perfect working order, and it will be seen that an arrangement of right and left hand screws provides the means of adjusting the distance between the tongues at any time. In a wood-paved road such a pair of points will soon disclose the fact that the track gauge is very likely to vary, and that it is not sufficient to keep the two tongues at an invariable distance: they must be so adjusted as to shut tight against the castings to whichever side they may be thrown. If the tongue of an ordinary moveable point is prevented by dirt or other cause from being thrown quite clear of the groove, the car will probably be deflected into the wrong groove: with coupled points a similar defect may throw the car off the track altogether.

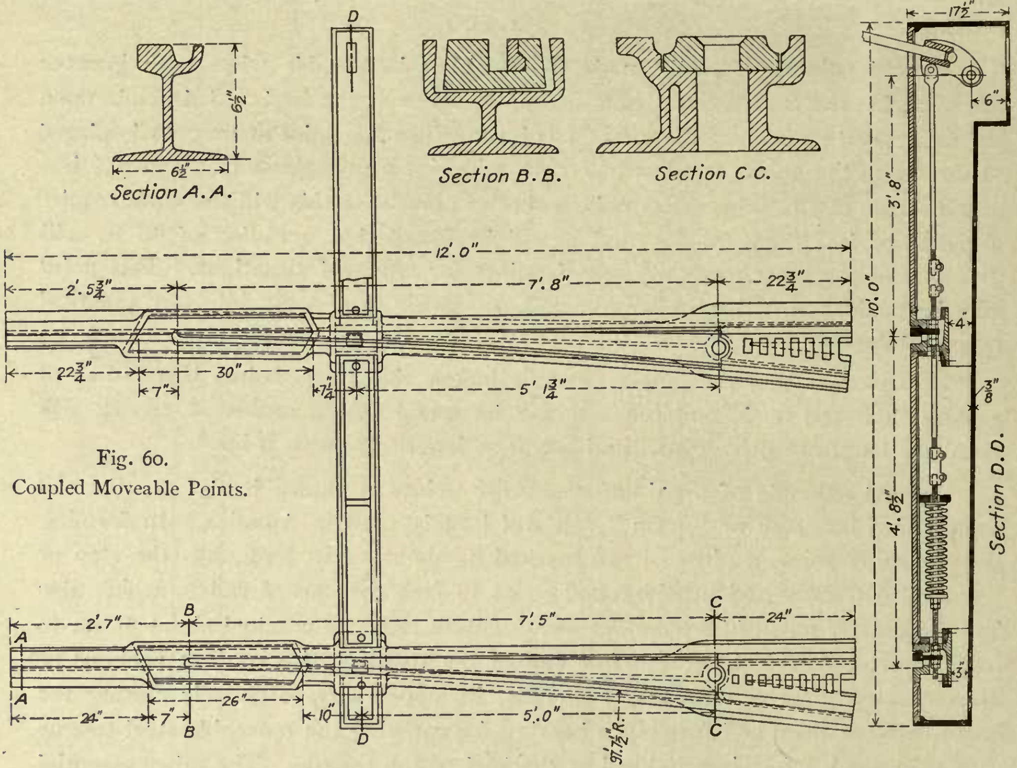


Fig. 60.
Coupled Moveable Points.

The cross sections show some variation from the usual shape of points, which have apparently been introduced to simplify the patterns in the steel foundry.

CHAPTER VIII.

CROSSINGS.

CROSSINGS form a detail of tramway construction calling for persistent attention on the part of the engineer; the crooked streets of an average English town are most effective in preventing any standardisation of the angles at which the lines of two rails shall cross each other. Practically such angles can only be fixed in passing places on a single line, and in the cross-over roads of a double line. Some little may be done at junctions where the lines branch off at right angles; in most of the other cases the angle is fixed by the surroundings, and the crossings must be made to suit.

As to the loops and passing places, it will be found that an angle of about 1 in 6 is the smallest that it will be convenient to take as a standard. The proper "lead" to be given to the crossing, or its distance from the toe of the point, will then depend upon the gauge and certain other considerations which may be outlined as follows, mathematical niceties being omitted :—

To fix ideas, suppose the gauge to be 3 ft. 6 ins., and the width of middle-way to be 3 ft. 6 ins. also, as in fig. 61. Then, dealing with the line of one rail only, the centre C of the crossing will evidently be the centre of the two curved branches; the oblique line F C K cutting through the straight rails at the angle defined as 1 in 6 fixes the angle at the centre of the crossing, and will be a tangent to each of the curves diverging from this point in opposite directions. As the arcs are on opposite sides of the tangent, the curvature changes in direction at this point, and the oblique groove in the crossing would be the central portion of an elongated S curve. In practical work no attempt is made to curve this part of the groove, partly because the curvature is too small to be shown effectively, but principally because a sharp reversal in curvature is very objectionable in working, especially with cars having a fixed wheel base. The curvature of a line should never change suddenly, and there is still more reason why it should not be suddenly reversed.

Assuming that a length of 6 ft. through the crossing is straight, or 3 ft. on each side of the centre, we fix the tangent point D in fig. 61. The proper lead for the crossing is then fixed in this way. Produce the tangent C D to meet the outer line in F, and make F H = F D; then H is the toe of the point. Draw C G

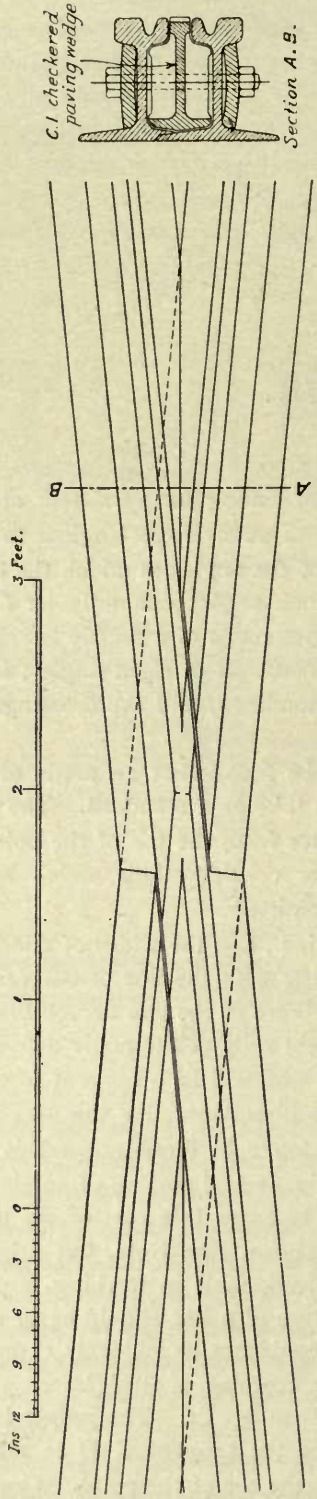


Fig. 62. Built-up Crossing for Girder Rails.

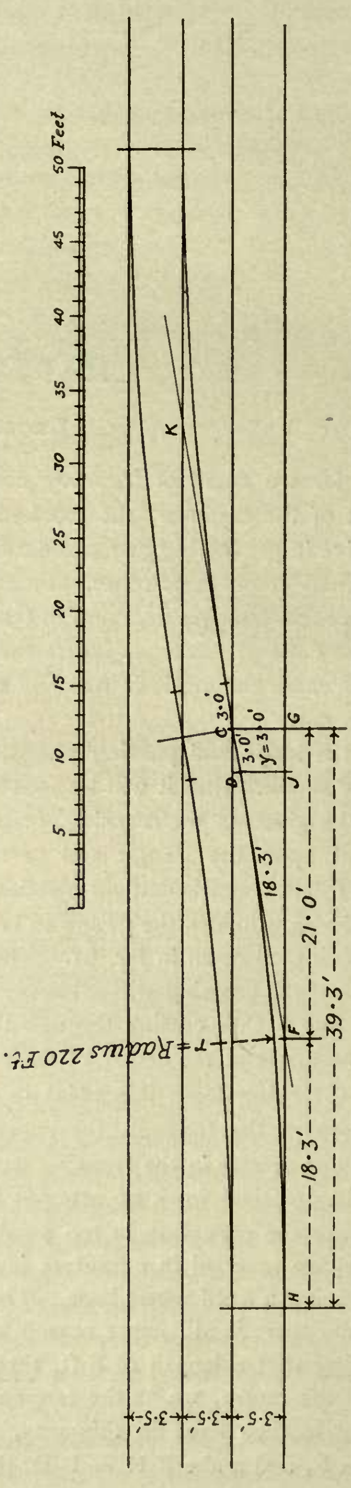


Fig. 61. Crossing Diagram.

perpendicular to the main line, then G F $= 6 \times 3{\cdot}5 = 21$ ft., and F C $= \sqrt{(FG^2 + CG^2)} = 21{\cdot}3$ ft., so that F D $= 18{\cdot}3$, and the lead is $18{\cdot}3 + 21 = 39{\cdot}3$ ft.

The radius of the connecting curve H D may be found thus. Draw the perpendicular D J (which $= 3$ ft. very nearly), making F J $= 18$ ft.; then H J $= 36{\cdot}3$ ft. Calling this x, and J D $= 3{\cdot}0$ ft. $= y$, we have from the equation to the circle (y being comparatively small)—

$$
\begin{aligned}
x^2 &= 2\,r\,y \\
r &= x^2 \div 2y = 36{\cdot}3^2 \div 6 \\
&= 220 \text{ feet.}
\end{aligned}
$$

These elements give a rather long cross-over, the total length being about 79 ft. There is no particular objection to this, but it is rather too long for the end of a loop on a single line, and the lead may be shortened to 35 ft. with some advantage, and the same crossing made to serve for both loops and cross-overs. It is evident that the lead depends upon the angle of the crossing, and to a less extent upon the length of the straight section C D. Increasing this to, say, 4 ft., F D, and therefore F H, will be shortened 1 foot, and the lead also shortened to the same extent. It is, therefore, evident that the lead is practically determined by the angle given to the crossing.

Built-up Crossings.—

Setting aside for the present the general question of junctions and special angles, and dealing with the crossings themselves, it may be said that the neatest and best looking work is obtained when the crossings are built up from the rails themselves, as shown by the example in fig. 62. The two rails are halved into each other, one is intact throughout on the top, and the other on the bottom. A pair of fish-plates of the ordinary section are bent to fit the external angle; suitable cast iron blocks or distance pieces fitted inside, and the whole bolted up. The structure may be further stiffened by one or more sole-plates underneath, and the outer distance-pieces may be brought up with a checkered surface to form paving wedges. The groove belonging to the discontinuous rail on top is planed out of the other rail; or by a little patience may be quite satisfactorily cut out with cold sates and chisels.

Crossings built up in this way may be readily adapted to suit any curve in the streets, no matter how awkwardly placed; they have a flexibility which is sadly lacking in a cast crossing, and it is easy to get smooth perfect curves where they are used. Unfortunately this is about their only merit, and they are quite unsuited for anything but the lightest non-mechanical traffic. At the part where the tread on one line is intersected by the groove of the other, more than half the metal which has to carry the traffic is cut away, and part of what is left has to carry the traffic of both lines. The result is very rapid wear and tear, and the most important part of the structure is quickly pounded into a hole.

Cast Steel Crossings.—

For this reason steel castings have to be used, this material being so much harder than the metal used for rails; the casting furthermore gives an opportunity of partially filling up the grooves so as to catch the wheel flanges, and so relieve the wear and tear at the place where it is greatest. Fig. 63 shows examples

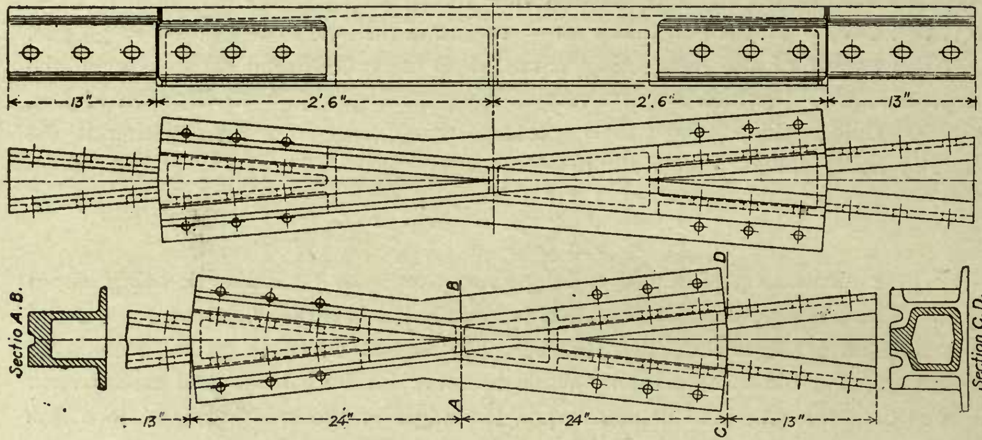


Fig. 63. Cast Steel Crossing.

of such castings. The ends to which the rails are secured are shaped into a kind of distance piece, fitting between them, and checkered on the top to form part of the street surface. With a small angle, say 1 in 5 or less, long bolts may be used, passing through rails and fish-plates as well as the intervening casting; but for larger angles it is better to have the casting chambered out, so that short bolts may be put in from the inside. The long bolts have an imperfect grip owing to the oblique angle at which they act, and they soon work loose; the momentary stretching of a long bolt under vibration may also have something to do in bringing this about. For still larger angles it is better to finish the casting to the same section as the rail, and to use a pair of the ordinary fish-plates.

The shorter the casting is made the more manageable it is in laying, and the more easy it is to hide any little irregularities in its shape or angle. But in general the ends of four rails have to be connected up to it, and space must be found for all these joints. Furthermore, it is quite necessary to avoid getting these points of weakness too close together, and the length of 4 or 5 ft. which the "frog" crossing shown in fig. 63 usually assumes is too short for permanent stability. The joints in such a casting are further weakened by cutting away a part of the flanges of the rails in order to get them together.

Leg Crossings.—

This source of weakness is avoided in the "leg" crossing shown in figs. 64 and 65, where the crossing terminates at each of the four corners by an extended "leg," finishing to the section of the normal rail, so that all four joints are made with the ordinary fish-plates and bolts alone, as in other parts of the track. This makes the casting about 8 ft. long, and the increased width at the ends makes it far more capable of withstanding the rocking movements liable to arise from the passing load being applied to one side only of the casting as the car wheels pass over the joints.

Fig. 64 is a crossing at 1 in 4½ and fig. 65 a crossing at 1 in 6. They are Messrs. Hadfield's patterns, and are made of "Era" manganese steel.

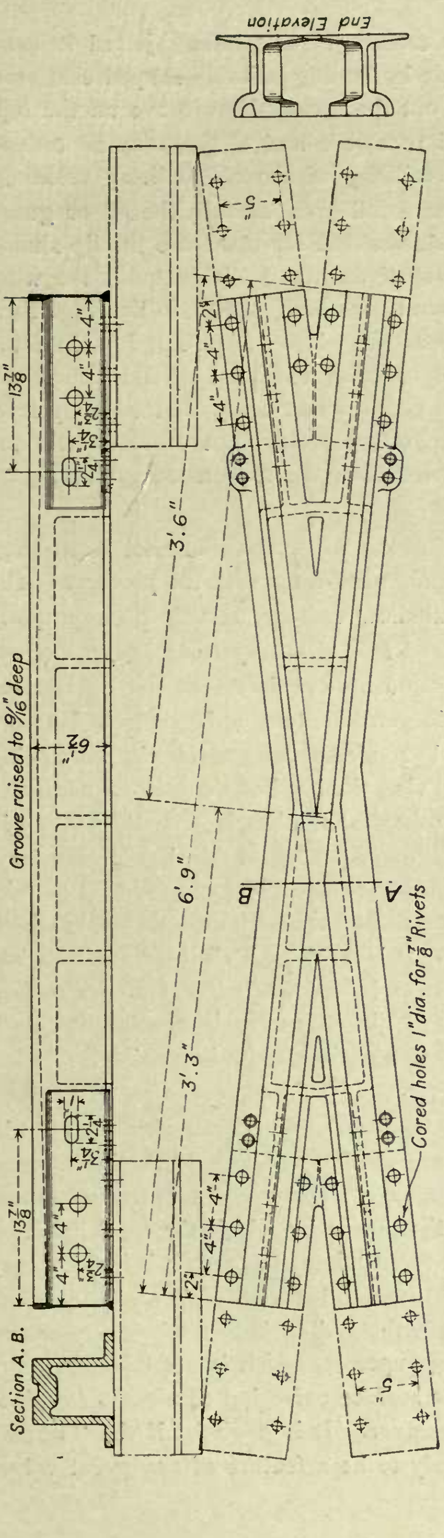


Fig. 64. Leg Crossing 1 in 4½.

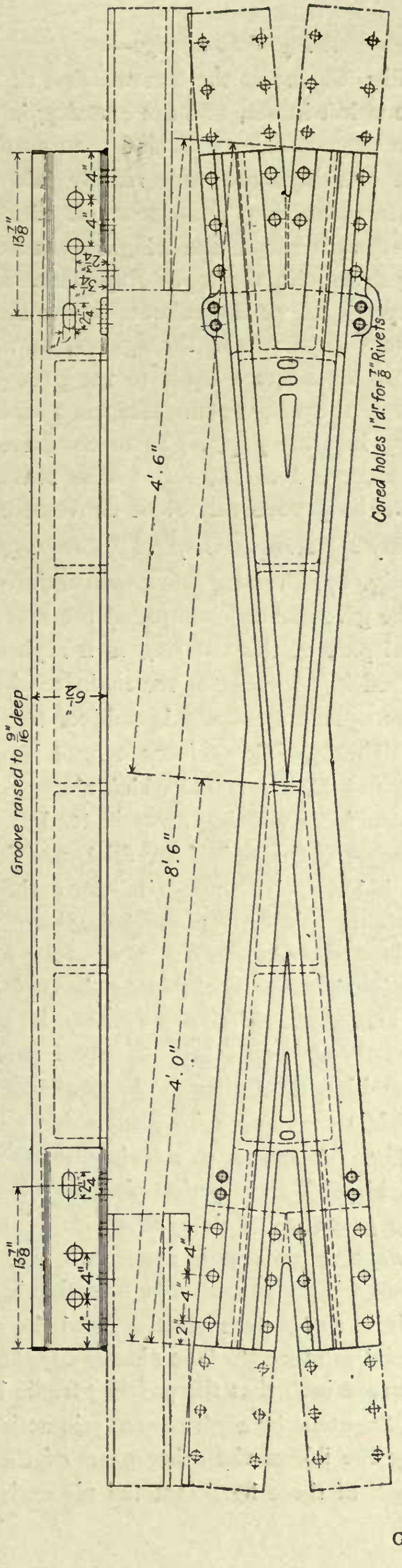


Fig. 65. Leg Crossing 1 in 6.

Lloyd's "Wing" Crossing.—

Fig. 66 shows the construction of this crossing. The rail subjected to most traffic is left intact, and the crossing is made by bolting suitably shaped cast steel wings to each side of it, and then cutting out the connecting groove on the top. These crossings are very readily laid and renewed, and easily adapted to any curvature, as they possess much of the flexibility of the old built-up crossing. The example shows the wings jointed up to a full grooved rail, the lip or guard being flush with the top. Experience has shown that for town use the lip should be kept ⅛ in. or thereabouts below the level of the tread. This spoils the wing crossing, as shown in the figures, as the wheels crossing the main line lose their support for a space equal to the groove, *plus* the width of the lip; *i.e.*, half the width of the whole rail. This is avoided by cutting away the lip and fitting the casting into the gap, so as to complete the groove, and bring that edge up level with the tread of the rail. This makes a good crossing, but unfortunately the gap in the groove cannot be conveniently cut out of the rail on the ground.

Kenway's "Renewable-fillet" Crossing.—

Fig. 67, showing the construction of Kenway's "renewable fillet" crossing, may be given as an example of the first method of dealing with the problem. The central part of the crossing is a separate shallow casting, resting on a properly prepared bed formed in the main casting, and held down by three heavy keys or cottars. This structure is subject to the same radical defect as the old Barker rail. The bearing surfaces cannot be made perfect; dust and grit gets between them, and the movement which always sets in sooner or later results in there being seven surfaces wearing away instead of one; viz., the head of the rail, two surfaces of contact at the bed of the fillet, and four others at the bearings of the cottars in their holes. In some situations the first-named appears to be of the least importance. When an exact duplicate of the renewable piece is produced to take the place of one worn out, it cannot be made to fit because no allowance has been made for the wear at the other six surfaces. It is as though all these surfaces had been arranged behind one another in series, and the same current of destruction passed through them all; an equal amount of disintegration is produced at each one, making the fitting of the duplicate renewable piece quite impossible.

Hadfield's Crossing with Renewable Centre.—

Fig. 68 shows a crossing made by Hadfield's Steel Foundry Co., Ltd., Sheffield, with an insertion piece of manganese steel at and around the intersection of the grooves. This type of crossing has been extensively adopted on recent tramways; is success is apparently due to the means by which the hard insertion is secured in its place. The insertion is not fitted "hard to hard"; it is fixed very loosely in the correct position, and the cavity then filled with molten zinc or some "special mixture." The zinc is capable of withstanding indefinitely any pressure per square inch that the passing traffic brings upon it, and it is not injured to any sensible extent by such electrolytic action or surface corrosion that can take place during the life of the other parts of the structure. It is doubtful if the "renewability" of these hard inserted pieces is likely to be a feature of any great value.

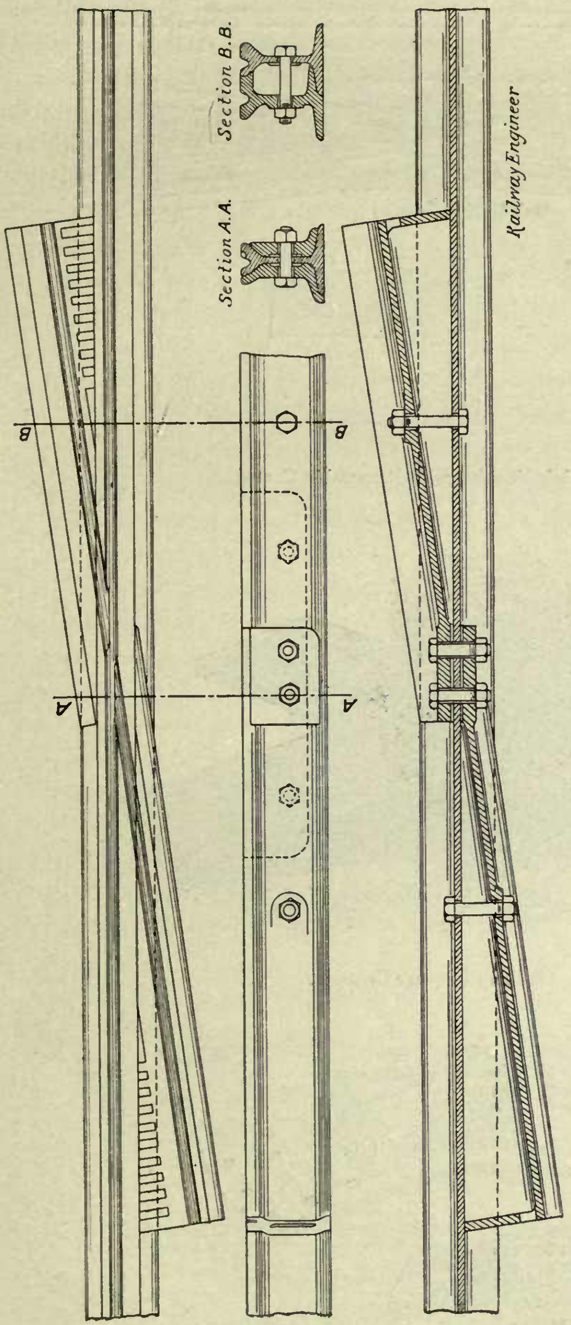


Fig. 66. Lloyd's Cast Wing Crossing.

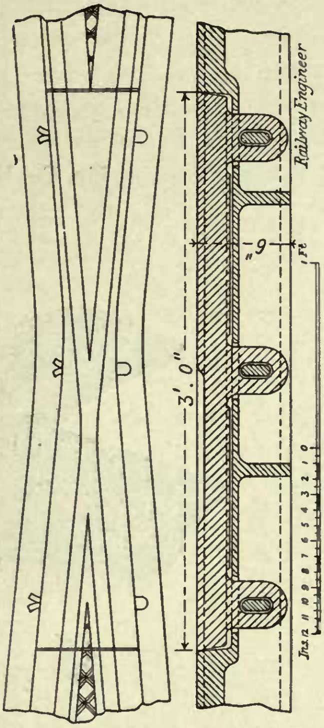


Fig. 67. Fenway's Renewable Fillet Crossing.

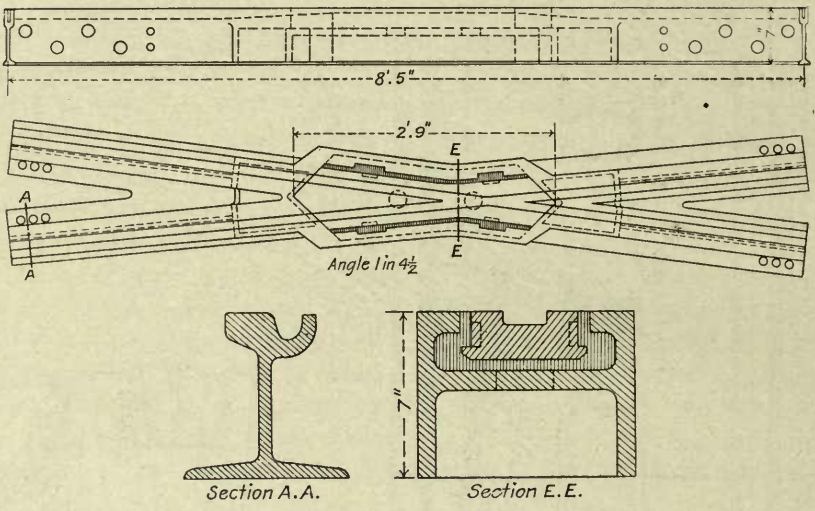


Fig. 68. Hadfield's Crossing with Renewable Centre.

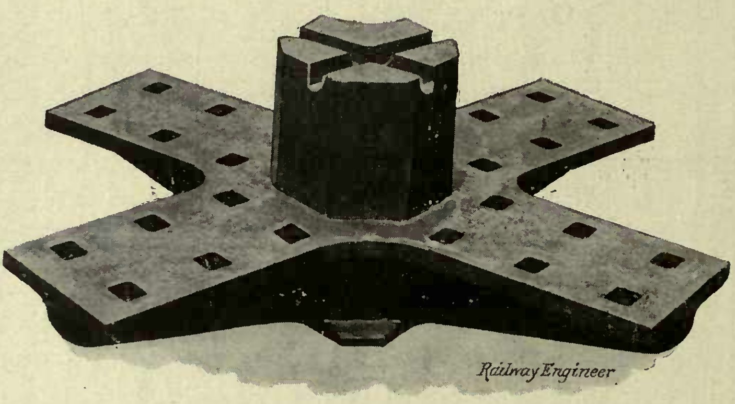


Fig. 69. Hadfield's Square Crossing.

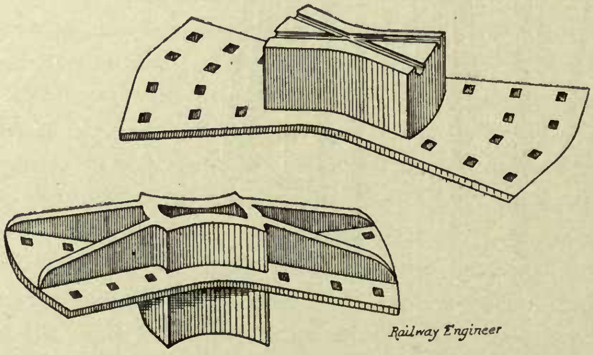


Fig. 70. Hadfield's Acute Crossing.

When they are worn out so far as to require renewal, it is probable that the condition of the other parts of the main casting will not justify the expense of cutting or melting out the inserted pieces and fixing fresh ones.

Hadfield's Square and Acute Crossings.—

Fig. 69 shows a new type of crossing introduced by Messrs. Hadfield, the grooves being at or near right angles and the area of the casting reduced to the smallest practical dimensions on the street surface: the abutting rails take a bearing upon, and are bolted to, the flat members of the four-armed cross forming the lower part of the casting, and which is to be entirely bedded in the concrete foundation. The joints are finished by fish-plates of the usual section bent to fit the angle between the rails, and bolted up in the ordinary manner.

When this type of construction is used for any other than a right angle, it is evident that the upper portion, against which the rails are jointed, will have to be elongated in one direction, to afford sufficient breadth at its ends for the heads of the adjacent rails, and the bent fish-plates might have to be omitted in the acute angle, and other details would have to be altered which need not be here specified. Fig. 70 illustrates such an acute angled crossing; in the lower diagram the crossing is inverted so as to show the construction of the bottom parts.

Askham's Square Crossing.—

A square crossing of quite a different type is shown in fig. 71 as made by Messrs. Askham Brothers & Wilson, Ltd. When a cluster of crossings at right angles is required, the maximum distance between them can only be the width of the gauge, or that of the middle-way, whichever may be the greater. The castings then can be made to abut up to one another without any intervening pieces of rail, and still be kept of a moderate length. All this conduces to good work; it is homogeneous throughout, and the labour of cutting and fitting the pieces together on the ground is reduced to the lowest possible minimum. It may be taken as an axiom that the stability of any piece of special tramway construction will be inversely proportional to the amount of labour and fitting that has to be done on the ground to get the parts into their proper places.

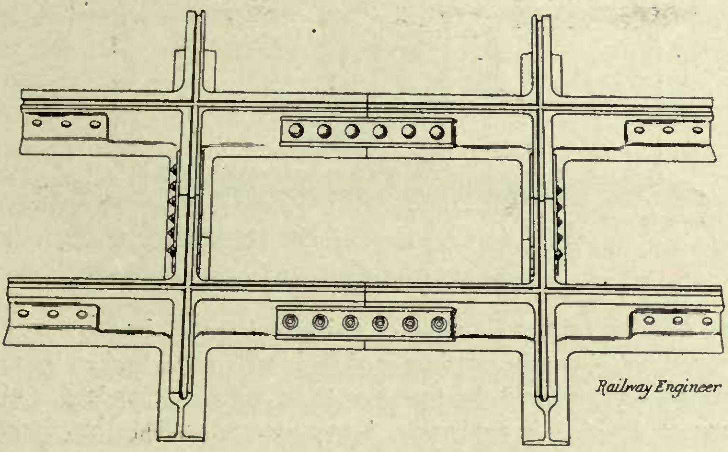


Fig. 71. Askham's Tramway Star Crossing.

Tramway and Railway Crossings.—

It is sometimes necessary to cross a railway on the level, when each crossing will have to conform to the section of the tram rail on one line, and to that of the railway rail on the other. The tramway engineer in these cases will generally find that the work will have to be subject to the approval of the owners of the railway. The most objectionable feature of these level crossings is the wide gap that has to be made in the head of the tram track to give room for the railway wheel flanges, which are about double the thickness and double the depth of the flange of a tram car wheel. Fig. 72 shows the construction of such a crossing on the Stockton-on-Tees tramways, as made by Askham Brothers & Wilson, Ltd. The rounding off of the internal angles of the casting is quite an unusual feature, and not to be recommended where the crossing has to form part of a paved street surface.

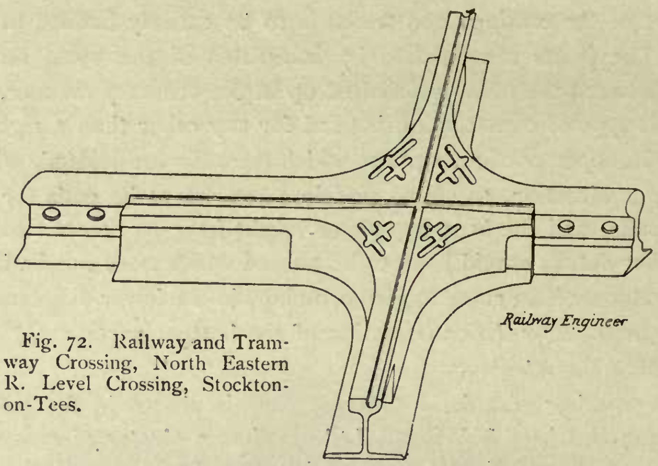


Fig. 72. Railway and Tramway Crossing, North Eastern R. Level Crossing, Stockton-on-Tees.

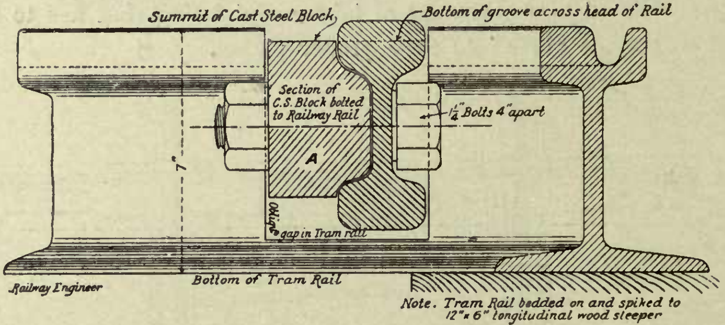

Summit of Cast Steel Block
Bottom of groove across head of Rail
Section of C.S. Block bolted to Railway Rail
1¼" Bolts 4" apart
A
7"
Oblique gap in Tram rail
Bottom of Tram Rail
Railway Engineer
Note. Tram Rail bedded on and spiked to 12" × 6" longitudinal wood sleeper

Fig. 73. Railway and Tramway Crossing.

Fig. 73 shows a railway crossing of a different type. In this case the railway company would not allow the continuity of their rails to be broken by the insertion of any castings, and required the tramway to be quite independent of the railway, and not connected with it in any way. A gap was cut in the 7 ins. tram rails wide enough to take the head of the railway rail and give a space of 1½ ins. for the wheel flanges, and deep enough to accommodate the 5 ins. bull-headed rail. These gaps were cut out in the planing machine, and the tram rail foot was left intact. To give an adequate bearing for the tram rail, it was set upon, and securely spiked to, a 12 ins. × 6 ins. longitudinal sleeper. A shows a cast steel block bolted to the railway rail so as to afford a bearing for the flanges of both railway and tramway wheels. This was possible because the company use this level crossing as a tram-road only, and the rails therefore have not to carry the heavier loads of locomotives. These crossings have stood very well for a number of years, but the jolt the tram cars suffer in passing over the 1½ ins. gap is a very objectionable feature, although it is greatly mitigated by the blocks A.

Compound Crossings.—

In laying out complicated junctions, it is very often found that three grooves intersect each other within such a small space that one casting has to be made to accommodate them all. Sometimes the intersection of three grooves leads to the necessity of six rails having to be joined up to one casting; it is difficult enough to make a good job when four rails are jointed to the one casting, and another junction greatly increases the platelaying difficulties. Speaking generally, it may be said that these compound crossings involve the making of expensive special patterns, and other complications which will be readily understood. It is possible that in depôt work, by a little judicious alteration in the curvature or position of the points, they might be avoided, and the engineer will have to consider in each case whether it is worth the while : that is to say, whether one compound crossing which involves six joints will be better than splitting this crossing up into three separate pieces of special angles, with an increased, and perhaps double the number of joints. Where they are required in street work, it is generally impracticable to alter the positions of the points or the curvature of the rails : the crossings must be taken as worked out upon the plan : in street work the limits of deviation will not admit of any great variation in the position of crossings.

Fig. 74 shows one of the compound crossings, as constructed by the Hadfield Steel Foundry Co., Ltd., where the grooves form a triangle of specially small dimensions. Fig. 75 shows a larger triangular compound crossing constructed by Askham Bros. & Wilson, Ltd. Sometimes the crossings fall very near the points, and may even form part of the same casting, or may be bolted direct to the wide end of the point. Fig. 76 shows such a structure made by Askham Bros. & Wilson, Ltd., and fig. 77 shows one made by F. H. Lloyd & Co., Ltd., in which the crossing and the point all form parts of the same casting.

Built-up Crossings.—

A great part of the expense of crossings and other tramway special works arises from the necessity of having to make a fresh pattern for every minute change in the angle involved. The angle of a crossing is a dimension which has to be exact; the length is a secondary matter—a platelayer can always arrange for this by cutting his rails, or cutting a closure piece, to suit any irregularities in the length; but he has no means of adjusting any variation in the angle, especially perhaps when that angle depends upon the radius of a curve, the width of the gauge, and the actual positions of several other crossings, all equally inflexible in this respect.

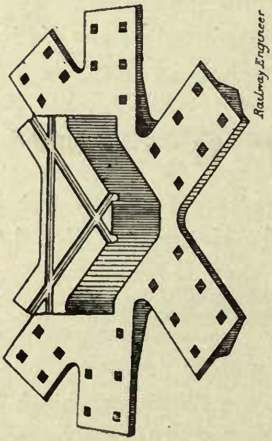


Fig. 74. Hadfield's Cast-Steel Crossing.

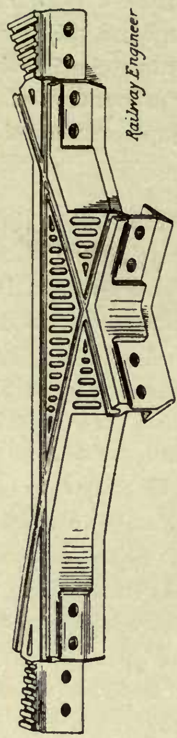


Fig. 75. Askham's Cast-Steel Compound Crossing.

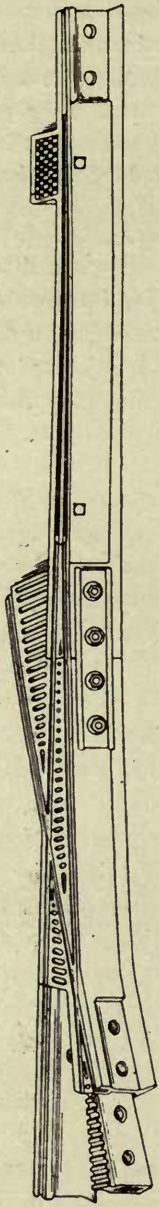


Fig. 76. Askham's Compound Crossing fitted to Patent Moveable Point.

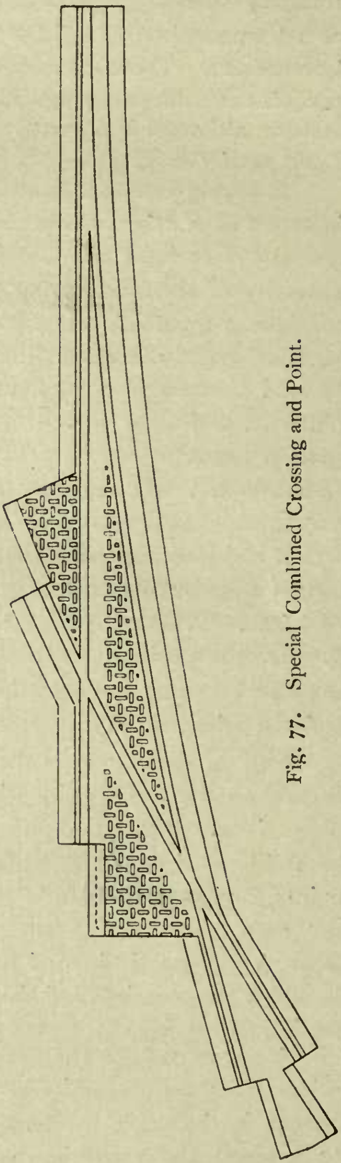


Fig. 77. Special Combined Crossing and Point.

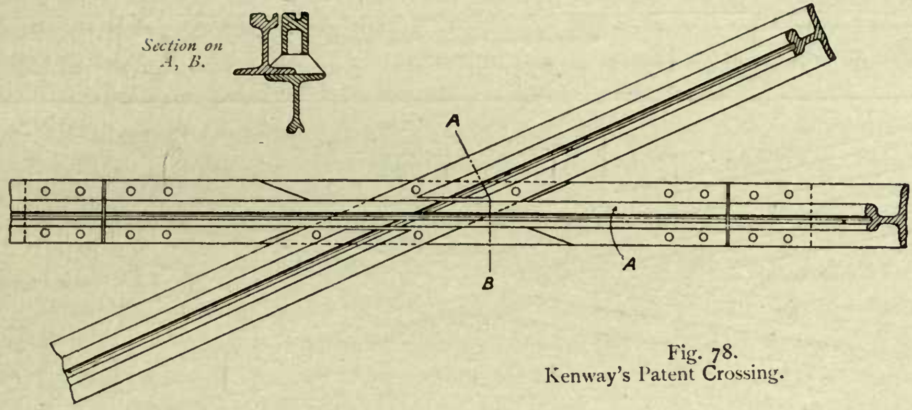
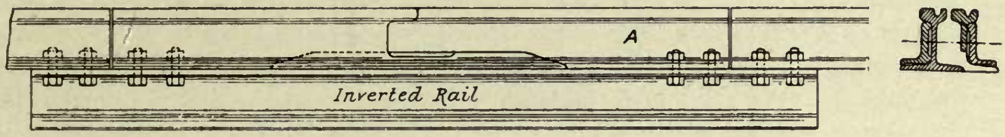


Fig. 78.
Kenway's Patent Crossing.



In fig. 78 (Kenway's patent) is shown a crossing recently introduced, in which an attempt is made to avoid some of this special pattern making and to produce a crossing which shall possess, in part at least, some of the flexibility which characterised the crossings which used to be built up out of the rails. In this crossing the central piece marked A, about six feet long, is a casting formed to the section of rail at each end, and carried through to the section of that rail on the top, except that the groove in the central part is partially filled up, and its lip is also brought flush with the head of the rail, this central part being a length, about one-third of the total, is formed of a box shape, with a web on each side extending about 4½ ins. in depth, and at the ends spreading out to blend with the flange of the ordinary section. In forming a crossing, a length of the ordinary rail is taken and a gap cut through in the centre at the angle required, and extending to such a depth as to afford room for the central parts of the casting referred to, and still leave the foot of the rail intact. The casting dropping into this gap is fished up to the ends of the abutting rails in the usual manner, and may be further secured by being bolted to an inverted piece of old rail fixed in the concrete, as shown in the figures; or what appears to be even better, is to carry the web through the central part of the casting instead of forming it of a box shape, and complete the joint by bending fish-plates of the ordinary section, as shown in the second cross section.

Hadfield's "Iron Bound" Crossings.—

Another type is illustrated by fig. 79, viz., Hadfield's Iron Bound Crossings. The four rails, having part of their flanges cut away on one side, are inverted and assembled together at the required angle on a massive iron plate: the gap between them, about 9 ins. long, is enclosed by proper moulding material, the cavity then filled in with cast iron, welding the ends of the rails together in one mass.

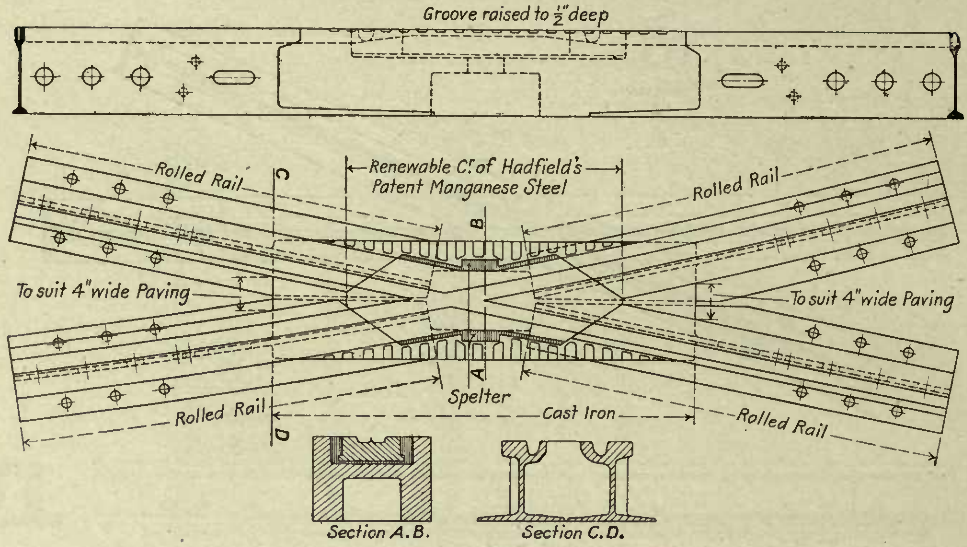


Fig. 79. Hadfield's "Iron-Bound" Crossing.

The mould is so arranged as to leave a cavity in the centre on the top surface adapted for receiving a suitable shaped piece of the "Era" manganese steel in which the grooves are formed; this manganese filling in piece is practically the only part of the casting for which a special pattern at the required angle has to be made. It will be noticed that the process resembles that described elsewhere in connection with the "cast-welded" joint.

Crossings for Special Work.—

The only way to ascertain the angles and other dimensions required at a given junction is to have an accurate plan of the roadway made to a large scale; to lay down thereon a plan of the lines to be constructed, and to ascertain from this the particulars required for the "special work," such as positions, &c., of the points and crossings, length of closures and connecting pieces, angles of crossings and radii of the various curves. The efficiency of the finished work will largely depend upon the accuracy of this plan, and the care with which the particulars referred to are taken from it. The angle of the crossing in the casting will correspond to the pattern, but the length of its arms will be apt to vary, perhaps because of the different heats at which the metal has been run. If these arms are not sawn off to length, the connecting pieces of rail must be varied to suit them, for the total distance between any two crossings, as determined by the plan, must be adhered to. In any complicated piece of special work the lines and crossing points are so connected together that a very small variation from the correct measurement may result in serious confusion in building up the work.

Angles of Crossings.—

Attention has already been drawn to the conveniences that would be gained by the use of standard angles for crossings, if such could be devised. In street work, however, nothing of the sort is possible, except at the cross-overs on double lines, and the loops or passing places on a single line. As an illustration of the difficulties, the writer has examined the map of a certain tramway system having about 50 miles of route, and leaving the crossings at cross-over roads and the passing places out of account, he found that the junctions at which crossings are required might be classified as follows :—

Single line junctions, square	5
Do. oblique	21
Double line junctions, square	3
Do. oblique	12
Triangles at depôts, &c.	13

Thus, out of 54 junctions, single and double, 8 only are at square corners, and there are at least 3 or 4 different radii to the inner curves, owing to irregularities in the width of the streets, and there are 33 other junctions at all sorts of angles, and 13 triangles; in every one of which the radius has been made as large as circumstances permitted. It is quite possible that if these 200 or 300 crossings were carefully sorted out, a certain number of duplicate angles would be found, but the number of such would be but a small proportion of the total. Furthermore, these figures include the tramways of four different companies, with five separate and independent maintenance organisations, and at least six different sections of rail, some 6 ins. and others 7 ins. in depth.

The possibilities of standardising the angles in these 54 junctions are therefore practically nil, and every crossing is dealt with as a "special." No general rule can be of much service in laying out such special work, except, perhaps, that it will be found advisable to cause all crossings to be the intersections of straight lines, or circles of known radius, *i.e.*, they should be kept clear of transition or other curves of indefinite radius.

Figs. 80 and 81 show two fine examples of special track work by Messrs. Hadfield. The first figure shows the lay-out at the Broadway, Ilford, and it will be seen that although there are only four thoroughfares concerned there are six complete double line junctions. There is also a double "scissors" cross-over. The crossings are of manganese steel throughout, and in some cases it has been necessary to compound four or five into one casting.

Fig. 81 shows the special works at the Clock Tower Junction, Leicester, and is the most complicated piece of ordinary tramway construction yet laid in England. There are five thoroughfares, with seven double line junctions and two single line junctions. Although more extensive than the work at Ilford, it is more simple in one respect; the junctions are all separate from one another : *i.e.*, all the points and the six crossings belonging to one junction are complete in themselves, and are not mixed with those belonging to another one, as they are in two of the cases at Ilford. It need not be remarked that this greatly facilitates the work of construction in the first instance, and there is no doubt it will facilitate the maintenance hereafter.

Fig. 82 shows the special work at Fitzallan Square, Sheffield, and is a combination of two double line junctions with a double line level crossing. As the wear and tear at this place is of a particularly severe character, the whole of this

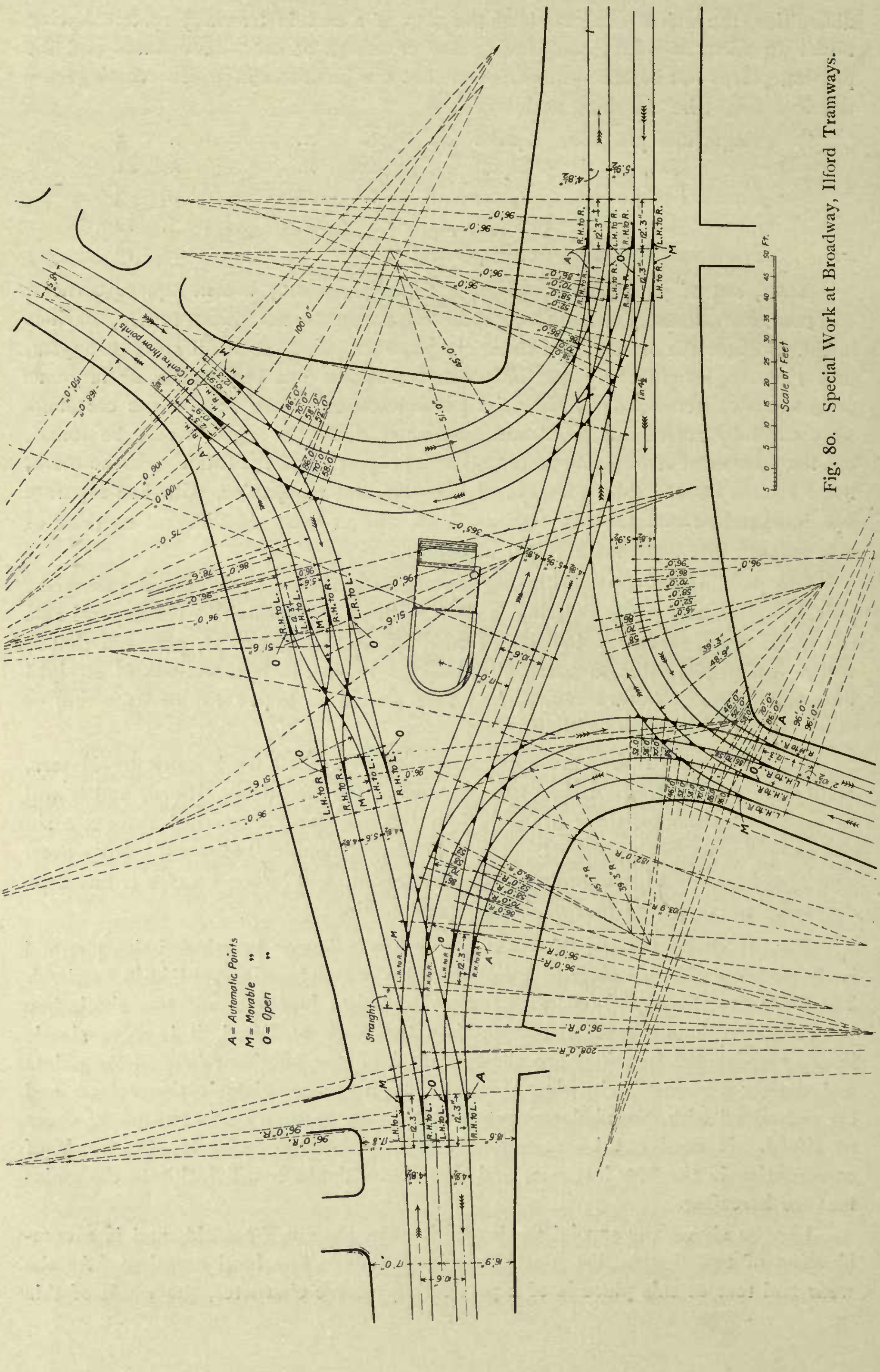


Fig. 80. Special Work at Broadway, Ilford Tramways.

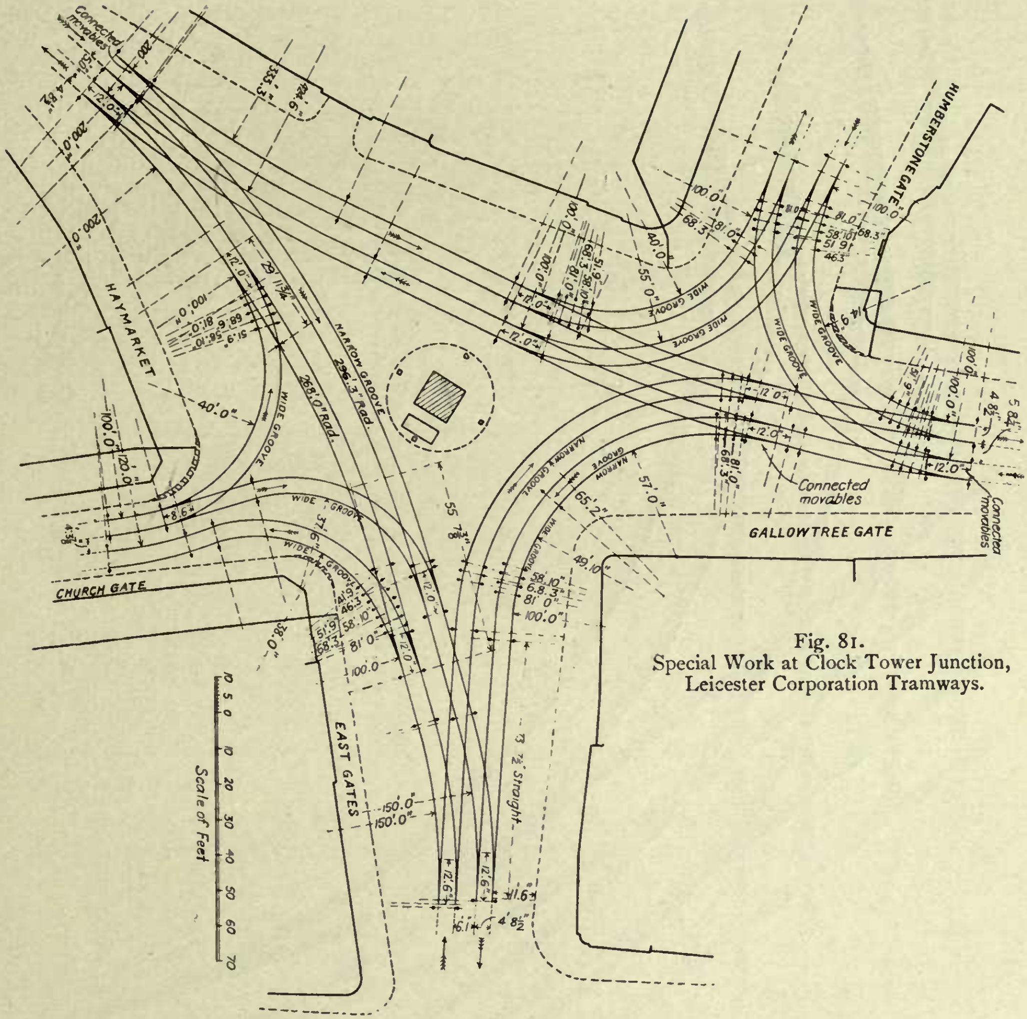


Fig. 81.
Special Work at Clock Tower Junction, Leicester Corporation Tramways.

work has been carried out by Messrs. Hadfield in manganese steel: the curved running rails also, where not connected to crossings, are of manganese steel, cast in 12 ft. lengths. There is no doubt that this is an exceedingly fine piece of work, and the difficulties in carrying it out were greatly increased owing to the fact that grinding with emery wheels is the only type of machine work possible on this material.

These complicated pieces of work occur naturally at the centre of a tramway system, and generally, therefore, in a part of the town where the interruption due to street works produces the maximum public inconvenience. To reduce this it is quite necessary to leave as little as possible to be done in the street: all rails should be cut and bent to shape, jointed up and fitted to the castings, tie bars fitted and every adjustment made upon a properly constructed floor. When this has been done it is a comparatively easy matter to pull it to pieces and fix it together

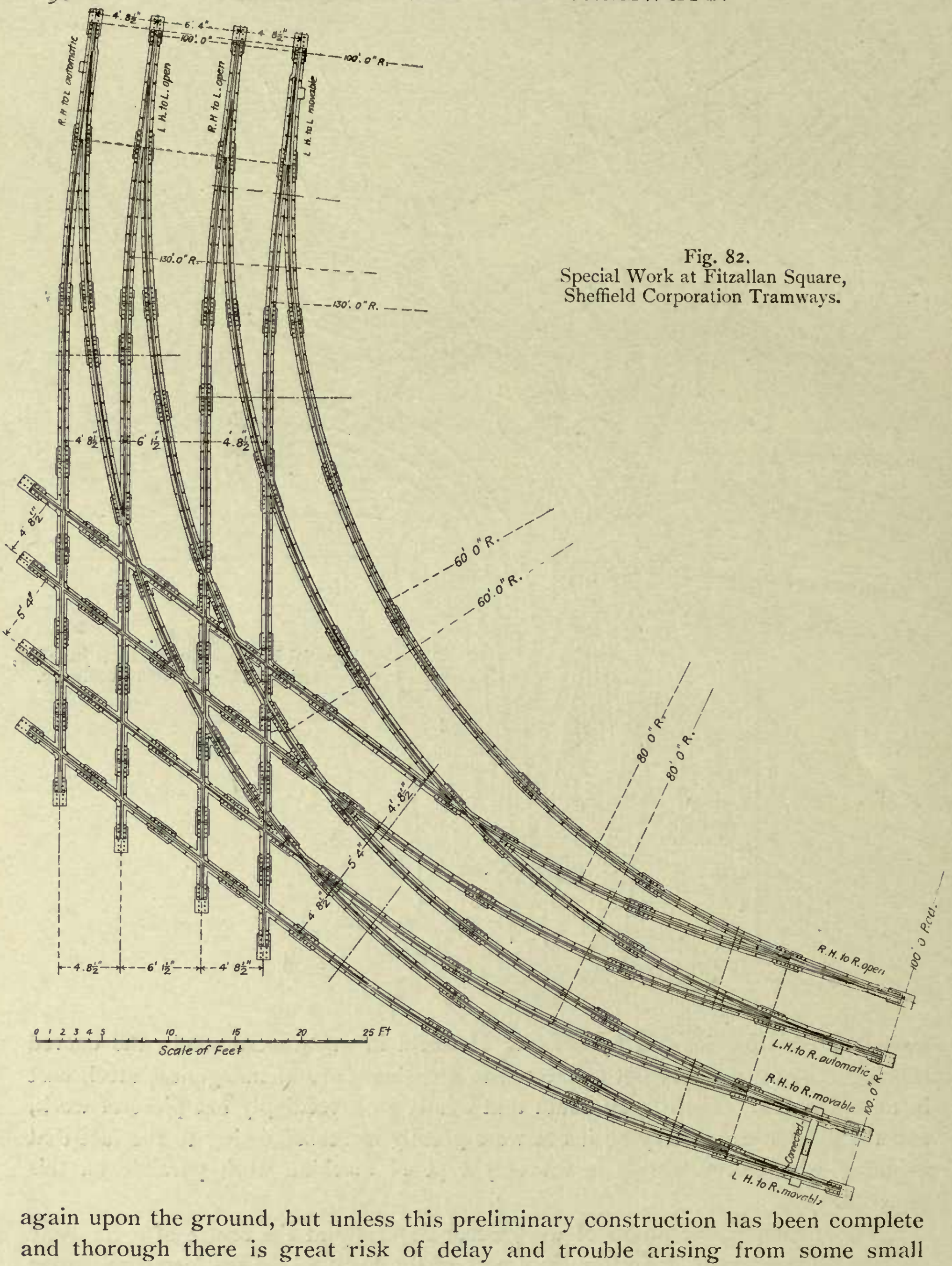


Fig. 82.
Special Work at Fitzallan Square,
Sheffield Corporation Tramways.

again upon the ground, but unless this preliminary construction has been complete and thorough there is great risk of delay and trouble arising from some small defect, causing very serious inconvenience.

Crossings for Depôt Lines.—

In depôt work there is a better chance, and it is quite advisable to keep to standard angles, leads, and lengths as far as possible throughout the sheds and the lines approaching them; this is not affected by the fact that a lighter section of rail is frequently used than that in the main streets.

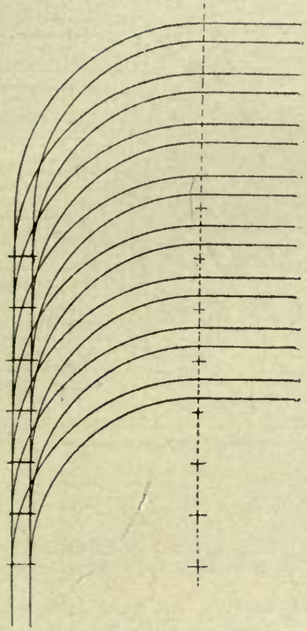


Fig. 83. Plan of Lines, Car Sheds at Leeds.
Mr. Thos. Hewson, City Engineer.

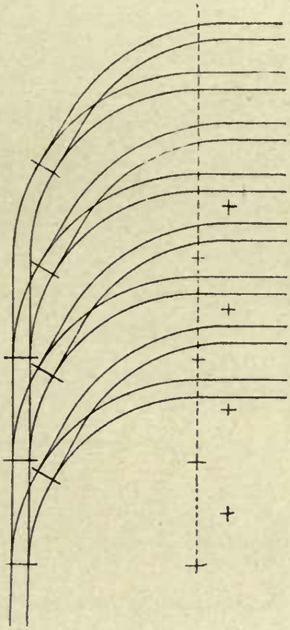


Fig. 84. Plan of Lines, Car Sheds at Halifax.
Mr. E. R. Escott, Borough Engineer.

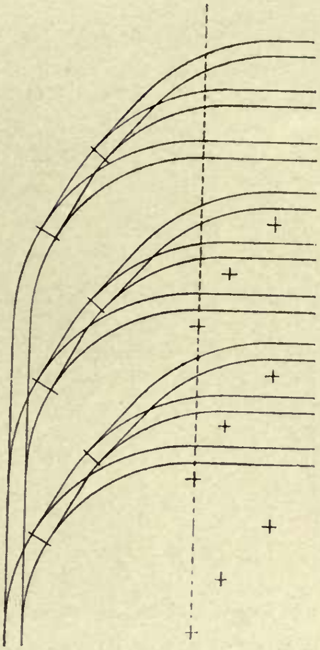


Fig. 85. Plan of Lines, Car Shed at Queen's Road, Manchester.
Mr. J. M. McElroy, Gen. Manager.

The following sketches show several ways in which the lines approaching a depôt may be laid out, and in every case 35 ft. is taken as the radius of the sharpest curve.

As these lines will always be traversed at moderate speeds, and as they are in positions where they can always be kept clean and in proper working order, it does

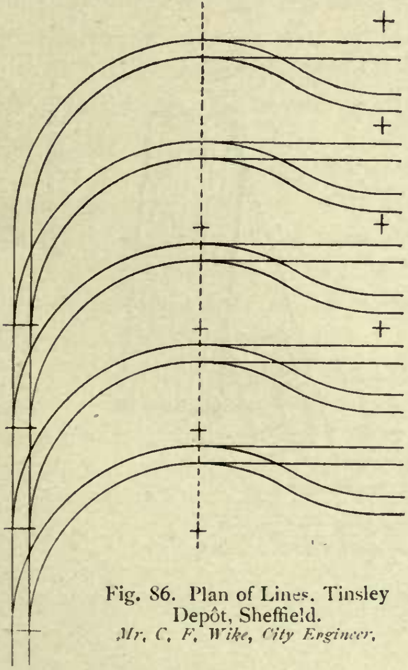


Fig. 86. Plan of Lines, Tinsley Depôt, Sheffield.
Mr. C. F. Wike, City Engineer.

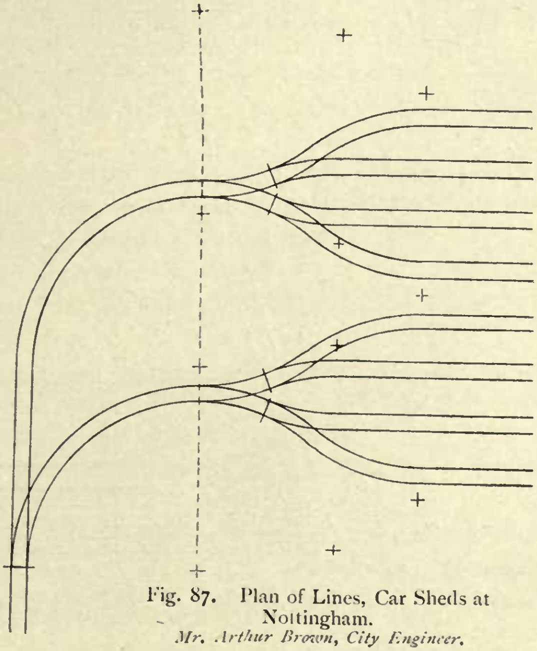


Fig. 87. Plan of Lines, Car Sheds at Nottingham.
Mr. Arthur Brown, City Engineer.

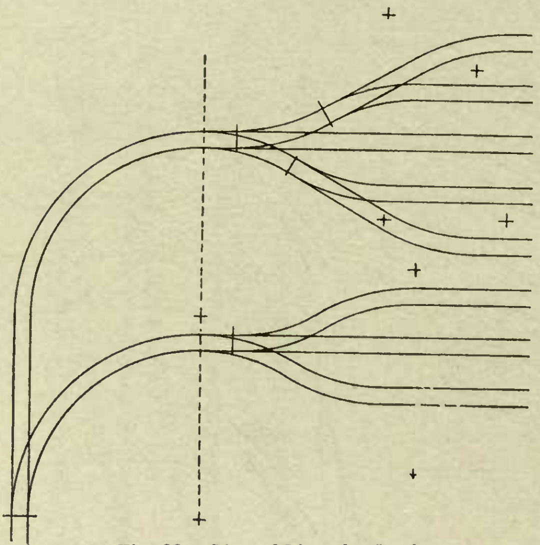


Fig. 88. Plan of Lines for Southport.
Mr. R. P. Hirst, Borough Surveyor.

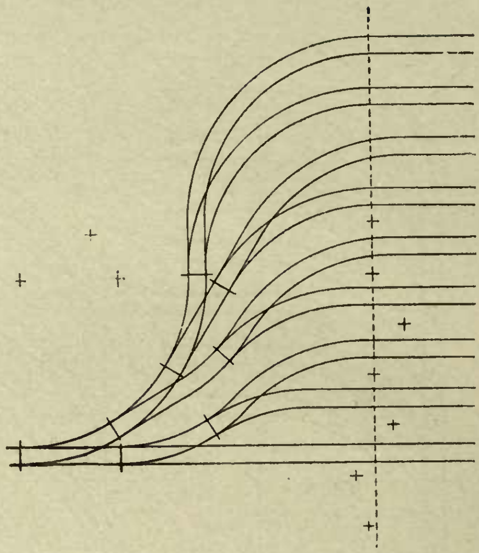


Fig. 89. Plan of Lines for Stockport.
Mr. J. Atkinson, Borough Surveyor.

not seem necessary to alter the curvature in some cases merely for the sake of getting a flatter curve, when such alterations would lead to the introduction of a crossing of a different angle to the rest of the work.

Fig. 83 is the plan adopted for the car sheds at Hull, at Leeds, and at many other places. It is most economical in space, the length of curved track not available for car storage being so short. With the radius assumed, 35 ft., this void space will be about 12 yds. in depth, or, say, room for one car on each branch road. What proportion this bears to the total space of course depends upon the lengths of the branch roads, and one object to be kept in view in laying out the sheds is to keep this proportion as small as possible.

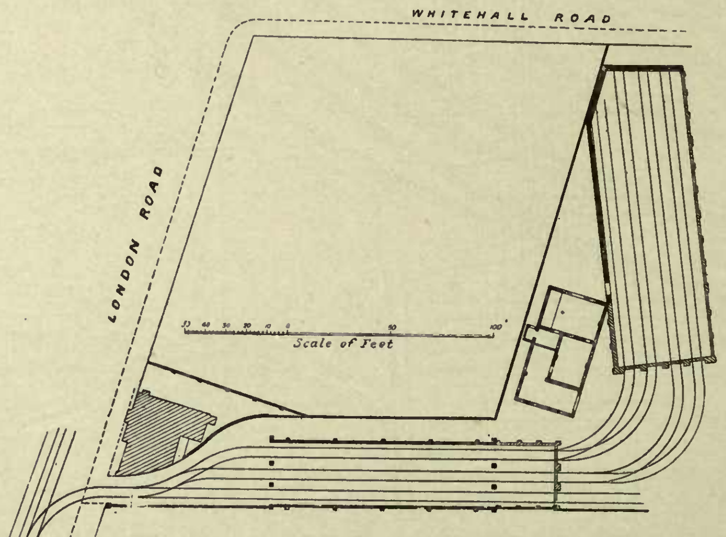


Fig. 90. Plan of Thornton Heath Depot, Croydon Tramways.
Messrs. Burstall & Monkhouse, Westminster, Engineers.

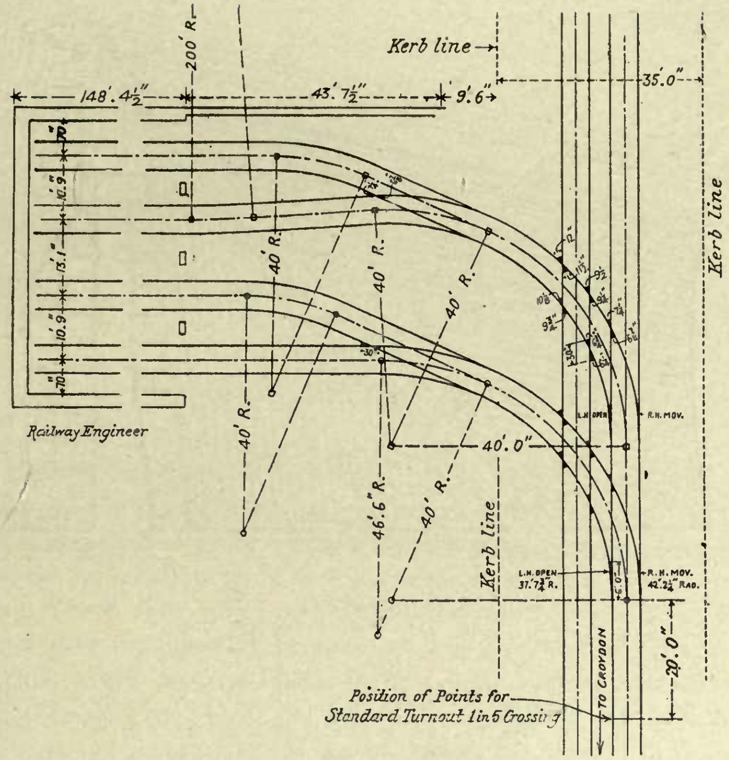


Fig. 91. Plan of Brighton Road Depot, Croydon Tramways.
Messrs. Burstall & Monkhouse, Westminster, Engineers.

Fig. 84 shows the arrangement at Halifax, each alternate branch starting from the preceding one and clear of the main road; the number of points is the same as in the previous case, but there are only half the number of crossings.

Fig. 85 is the arrangement of the tracks in the great shed at Queen's Road, Manchester, and may be shortly described as a further development of the ruling idea in fig. 84.

Fig. 86 may be said to be a diagrammatic plan of the lines leading into the Tinsley depôt at Sheffield. The plan differs from that example only in the more orderly arrangement of the branch tracks : and in a similar way,

Fig. 87 shows the arrangement adopted at Nottingham.

Fig. 88 shows the tracks leading into the shed at Southport, and varies but little from that at Nottingham.

Fig. 89 is a diagram of the arrangement adopted at Stockport, the plan being varied a little to eliminate non-essential features. This design is adopted to suit the peculiar "bottle-necked" form of the approach to the sheds.

Figs. 90 and 91 show the plans adopted for two of the depôts of the Croydon Corporation Tramways.

Fig. 91A is a plan of the tracks in the car shed at Milan : it is given as a very good example of the compact arrangement of special work arising from the small angle between main and branch lines. The length of connecting curve is reduced,

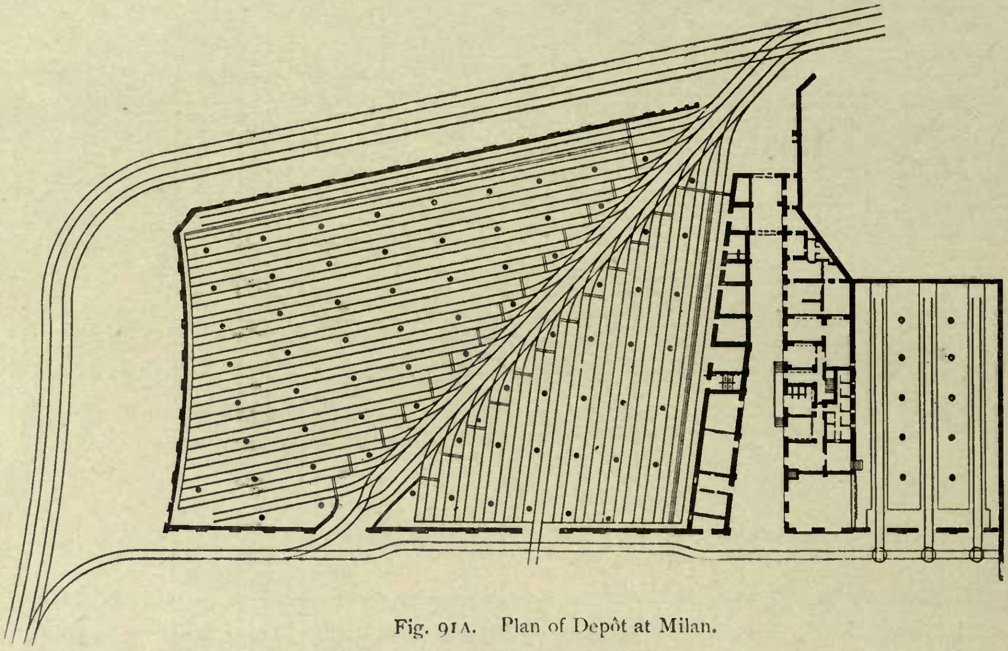


Fig. 91A. Plan of Depôt at Milan.

with a corresponding increase in that of the straight track. The overhead work is also simplified and the shunting facilities are improved. In general this plan will not lead to any increase in the storage space on a given area, but of course much depends upon the shape of the ground and the means of access to it. The example in fig. 91A is probably unique, but a partial application of the principle involved could have been made with advantage to some of the "lay-outs" that have been constructed in recent years.

* * *

CHAPTER VIII.

Bolts and Tie-Bars.

The efficiency of the joint depends largely upon the efficiency of the bolts used in holding its various parts together; if they be inadequate to the work they are called upon to do, the care and attention spent upon the other parts of the work are to a great extent thrown away. For general tramway work it may be said that bolts made according to the following specification will give satisfactory results.

"The bolts shall be made from the best iron, showing a perfectly fibrous
" fracture when broken, and capable of withstanding a strain of 24 tons per square
" inch before fracture, with an elongation of 20 per cent. in a length of 8 inches."

"The bolts to be machine made, forged with square necks and cupheads, true,
" square, and concentric with the shank, and to be fitted with square nuts. The
" bolts and nuts to be screwed with Whitworth Standard threads, full and well
" formed throughout, and of such a length on the bolt that when the nut is
" screwed into place two clear threads shall project outside the nut. The fit of the
" nut shall be such that when the bolt is half way in the nut, a spanner 9 inches
" long shall be required to bring the nut into position. The bolt and nut shall be
" of Whitworth Standard dimensions throughout, they shall be oiled hot, whilst
" free from rust and properly dried before packing."

For tramway purposes the sizes of the bolts will vary from ¾ in. to 1⅛ ins. dia., and the standard dimensions between these limits are as follows:—

Diam. of Bolt.	Area of Section.	Area at bottom of thread.	Threads per inch.	Thickness of nut.	Width of Hex. or Sq. heads and nuts across flats.
Ins.	Sq. in.	Sq. in.	No.	Ins.	Ins.
¾	·442	·304	10	¾	1·30
⅞	·601	·422	9	⅞	1·48
1	·785	·554	8	1	1·67
1⅛	·994	·697	7	1⅛	1·86

It is advisable to specify that any bolt may be taken as representing the bulk of the goods supplied, and which on being tested shall show results corresponding to those obtained in testing the original bar. It is not usual for an engineer to keep an inspector at the works to supervise the manufacture of the bolts in detail, but in any important job precautions should be taken to see that the specification is adhered to, such as taking power to inspect and test the work in any stage of its progress or after delivery. In these days of competition, when contracts are given to the lowest bidder, and unless the work gets into the hands of a firm with a reputation like that of Cæsar's wife, it is advisable not only to say what is wanted beforehand, but to see that it is supplied. Cases have been known where a special pile of bar iron has been kept at the works from which the inspector may take his samples for preliminary testing; these tests invariably come out satisfactory, but the iron for the bolts is taken from another pile.

It would be an easy matter to compute the stress brought upon a bolt by screwing up under given conditions of friction, length of spanner, force exerted by the platelayer, &c., but the result would not be of much practical use owing to the uncertainty in the value of the last-mentioned factor. The pull on the spanner by a workman who sets about screwing up a bolt tightly may be anything between 50 lbs. and 200 lbs., according to the strength of the man and the advantage of his position in giving the final wrench. A pull of 50 lbs. at the end of a spanner 2 ft. long would put a strain of about 6,000 lbs. on a bolt, or a stress of about 9 tons per square inch on the metal at the bottom of the threads of a ¾ in. bolt. This is obviously sufficient to destroy the efficiency of the bolt, because under vibration the momentary stresses under such conditions must certainly exceed the elastic limit, and hence it may be safely concluded that a bolt of this size is quite out of place for fishing up purposes. It is the Author's opinion that fish-bolts should not be less than 1 in. in diameter and that this is sufficient, for a bolt 1⅛ ins. diameter affords a clumsy obstruction to the paving around the joint.

There are various methods in common use for preventing the bolt from turning while being screwed; the most usual and one of the best is a square neck to the bolt fitting a square hole in one of the fish-plates. Other devices are an oval neck fitting into an oval or square hole; a pear shaped neck with a pear shaped hole; a square head fitting a longitudinal groove or recess in the fish-plate, and sundry others; all, however, are of about equal efficiency. The taper head fitting a taper hole in the fish-plate, shown on one of the sections (fig. 5, p. 32) already illustrated, is open to two objections : it requires an extra heavy plate in which to form the taper hole, and the rigidity given to the bolt introduces undesirable racking strains in the shanks by any small movement of either plate under the traffic. For the same reason tapping the holes in one of the plates so as to do away with the usual nut (as shown in fig. 11, p. 35) cannot be recommended, and the racking strains here come upon that part of the bolt least able to withstand them.

All bolts should be an easy fit in their holes; the holes cannot be drilled through all the members of a joint *in situ*, so that a driving fit cannot be used. There would be no practical gain in such a fit, because the parts connected by the bolt are subjected to such frequent severe stresses that a connection of this kind would only open up fresh points of wear and tear. Especially should there be ample clearance in the hole through the rail; expansion and contraction in a 90 lbs. to 100 lbs. rail may be controlled by a welded joint, but not by the shearing strength of two or three bolts.

For tramway work there is not much practical difference between square and hexagon nuts; in general for exposed situations the latter usually have the preference because of their better appearance and the advantage of being able to turn them with a suitable spanner in a more confined space. These reasons, however, hardly apply in tramway work, and in one respect the square nuts are better in having a better grip on the adjacent paving and grouting, and thereby giving a better check to any tendency to slack back that may show itself. It is certainly but rarely that this extra check is required, but is is perhaps as well to secure it even though the square nuts are a trifle the heavier.

Tie-Bars.—

These are used to keep the rails to gauge, and may conveniently be referred to here as they are very much the same class of material as the bolts. In the great majority of tramways of recent construction the form varies but little. It is generally a flat bar from 2½ ins. wide and ¼ in. thick to 2 ins. by ⅜ in., either notched at one end and screwed with a ¾ in. thread at the other, or screwed at both ends. The screwed ends are each furnished with two nuts and two washers, the length of the screwed portion being such as to allow sufficient play in its hole for the other end of the tie-bar to be brought into position after the rails are laid to gauge. The ends are passed horizontally through rectangular or half-round ended slots about 3 ins. by 1 in. in the web of the rail, and then, if they be notched, turned into a vertical position. The rectangular holes admit of their being moved so that they come between the rows of setts. The tie rods are usually placed 2 ft. 6 ins. from end of rail lengths and about every 4 ft. between.

An improvement in the construction of these bars has recently been introduced by Bayliss, Jones & Bayliss, Ltd., Wolverhampton, and is shown in figs. 92 and 93. The bars are made out of the solid, and no welding or swaging is necessary. The strip is formed in special rolls, giving a bar 2 ins. by 5/16 in. for the greater part of their circumference, the other part producing a section like *a* in fig. 93. This sec-

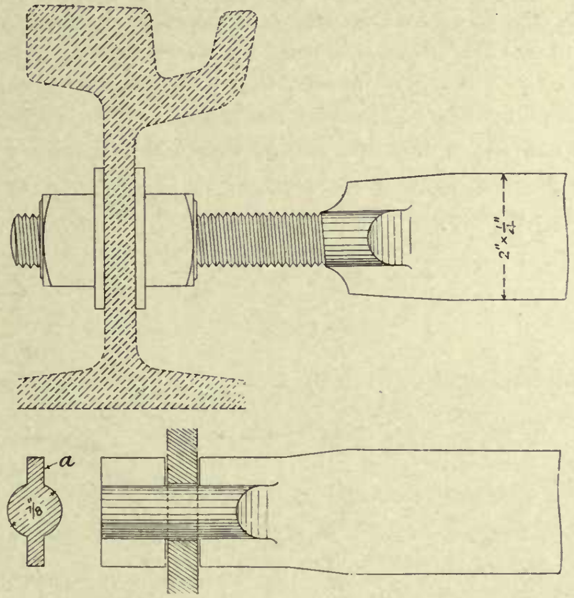


Fig. 92 & 93. Bayliss, Jones & Bayliss's New Tie Bar.

tion, which may be described as a $\frac{7}{8}$ in. round, placed in the centre of a $1\frac{3}{4}$ ins. by $\frac{5}{16}$ in. flat, extends for about a foot in length along the bar, and at intervals depending upon the gauge of the tramway for which the tie-bars are intended. The strip is cut up into lengths through this special shaped section; to form a screwed end, the projections or wings are cut off and the remaining round screwed with a full $\frac{7}{8}$ in. thread; for a notched end, the gaps are cut out of the projecting flats, leaving the $\frac{7}{8}$ in. diam. centre intact. It will be seen that this construction gives a thin deep body for fitting in the joints of the pavement, and also a full-sized section for either notch or screw.

The ends of the tie-bars thus described pass through the centre of the web of the rails, and have therefore but little control over variations in the gauge caused by the rail itself tilting over to the one side or the other. For this reason on some tramways angle bars have been used bolted underneath to the foot of the rails, or else flat bars of sufficient depth to allow of two bolts at each end passing through the web of the rail. Any of these devices suffice to hold a rail in position during construction, but they have little influence in preventing movement taking place afterwards : the rail must be so bedded as to be independent of their aid. A rigid tie-bar connection requires extra care in construction, as it may give an appearance of stability and firmness to an imperfectly laid road. The proper function of the tie-bars is to hold the rails to gauge while they are lined up and packed on their foundations, and the paving laid alongside them; they can play no appreciable part in maintaining the road in shape afterwards.

The above specification applies to wrought-iron, but bolts and other track fastenings are now more frequently made of mild-steel. For the London County Council track-work it was specified that this steel should be made by the acid, open-hearth process and be of a tensile strength not under 30 tons nor over 35 tons per sq. inch. Otherwise expressed an inch bolt taken at random from the bulk should stand a strain of not less than 16·5 tons nor more than 19·5 tons before fracture. From the table on p. 101 it will be seen that these are the strengths corresponding to the area of section ·554 sq. inch at the bottom of the thread. It was further required that a bar 1 inch diameter should bend cold round a 2 ins. diameter until the sides were parallel without shewing signs of cracking or fracture. Before delivery all bolts were dipped in hot boiled oil.

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CHAPTER IX.

TRANSITION CURVES.

TRAMWAYS cannot, as a rule, be laid out to definite curves; the lines have to follow the road, but since moderate speeds only are in question, the bends of an average road are not likely to cause difficulties in working the line. When the shape of the road, however, demands the use of curves of less than 100 ft. radius or thereabouts, it becomes necessary to consider the effect of the curvature itself apart from other questions, and the smaller the radius, the more important does the question become.

Circular Curves.—

Taking, then, 100 ft. as the limit, it may be said that in general all curves of a less radius than this should be constructed of true arcs of circles of definite regular curvature, the true curve being departed from only for certain specific reasons. The curvature of any piece of rail may be ascertained by stretching a string or tape of known length between any two points on the curve, and measuring the length of the offset to the rail in the centre. A convenient formula may be worked out thus :—

In the diagram, fig. 94, let r be the radius of the circle, l the length of the chord, and x the offset at its centre. This offset is part of the diameter through the centre and the middle point of l, the chord and the diameter intersecting at the point A. But two lines intersecting in a circle have the rectangles under their segments equal, hence

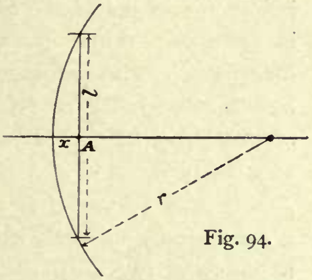


Fig. 94.

$$x\,(2\,r-x) = \frac{l}{2} \times \frac{l}{2}$$

or

$$2\,r\,x - x = \frac{l^2}{4}$$

In practice, x is always very small compared with r and l, and x^2 may therefore be neglected, whence

$$x = \frac{l^2}{8\,r}$$

These dimensions are all in feet; to express x in inches, multiply its equivalent value by 12, and we have

$$x'' = \frac{1{\cdot}5\,l^2}{r}$$

This gives the offset in inches for any given values of the radius r and the chord l. If 10 ft. be taken as the length of the chord we have

$$\text{offset} = \frac{150}{\text{radius}} \quad \text{and conversely} \quad \text{radius} = \frac{150}{\text{offset}}$$

The error introduced by neglecting x^2 is quite inappreciable, it increases as l

increases, but only amounts to about 1 per cent. of the true value when l is taken equal to r, and in practice it will always be considerably less.

Fig. 95 shows a handy form of straight-edge, 10 ft. long, for use in bending rails to specified curvatures. It carries a brass slide in the centre, which can be pushed out and clamped in any position, showing by a graduated scale the radius of the curve passing through the projecting end of the slide, and the two ends of the straight-edge. Fig. 96 shows these graduations half size; they get very close together when the radius is much over 100 ft. It would be quite possible to open out this end of the scale on the Vernier principle, so that a large radius might be more easily read, but such a plan would be attended with no advantages, owing to the impossibility of curving the rails themselves with such great exactitude.

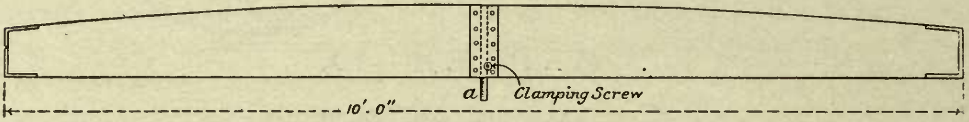


Fig. 95. Curve Gauge.

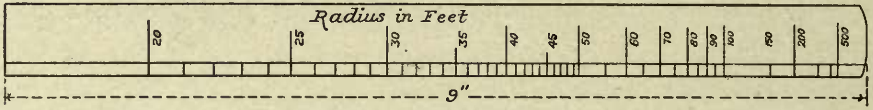


Fig. 96. Plan of Slide *a*.

All very sharp curves, such as those required in turning a right angled street corner, should be connected to the straight by properly constructed "*transition curves.*" The degree of necessity for such a curve may be said to depend in great measure upon the rolling stock: with four-wheeled cars having a short fixed wheel base, the necessity is much greater than it is with cars on bogies. Consider for a moment the example of a 21 ft. car on a 5 ft. 6 ins. wheel base, approaching on the straight a curve of 40 ft. radius at a speed of 8 miles an hour. In passing from the tangent point into the curve, the leading wheels are deflected 4½ ins. laterally before the trailers have left the straight; at the same time the front end of the car is deflected 11 ins. in the same, and the rear end about 6 ins. in the opposite direction. As these lateral displacements have to be effected in a little less than half a second, the result is a violent lurch tending to throw the car off the road, setting up strains in all sorts of undesirable places, and presenting other objectionable features.

It may be useful to examine this action a little more closely. The motion of a car round a curve is evidently similar to that of the moon round the earth; it is made up of two quite distinct movements, one being a translation along the curve, the other being a rotation round the centre of the wheel base. The speed along the curve is under the driver's control; the rotation is not so except in an indirect manner, viz., by varying the speed of the car. The rotation can only (at a constant speed) be effected without shock, by curving the rails as to cause it to commence gradually, work up to a certain maximum, and to then die away as gradually as it commenced, as the next stretch of straight is approached. This would point to the use of a curve of constantly varying curvature, so that as soon as the maximum rotation is reached it begins to die away again. In practice, however, there is no objection to the use of a substantial length of arc of constant radius in the centre, so that when the maximum is reached the rotation remains uniform, until the point is reached when it is necessary to begin to stop it again. As, however, it is obvious that the shorter the period of maximum is made, the more gradual will be the transition from rest to rotation and *vice versa*, it may be advisable to examine one or two curves that have been proposed, and in which the curvature varies throughout.

In comparing these different curves, it will be convenient to consider them all as applied to the same case; the object is to show the differences in the curves themselves rather than to indicate which would be the best under any given circumstances.

The case taken will be that of a curve to connect two straight rails B C and B D in streets at right angles to each other; each rail 10 ft. from the nearest kerb, the curve to pass through a certain given point A on the bisecting line, 14 ft. 9 ins. from the intersection, and selected as being the minimum distance it is advisable to allow between the rail and the nearest point of the kerb at the corner.

Parabolic Curves.—

Apart from circular arcs, perhaps the best known curve for the purpose is the common parabola. In fig. 97 the two straights meeting at B must be tangents to the curve; B A bisects the angle between them, it is the axis of the parabola and the point A is the vertex. These elements determine the curve completely. Make A E = A B, and draw C E D at right angles to A B; on C D describe by any of the well known methods a parabola, passing through A, and we have the required curve, C, A, D. From the nature of the curve, since A B = A E, B C and B D must be tangents at C and D. Its minimum radius of curvature is at the vertex, and = 2 A E, or 29 ft. 6 ins.; the maximum radius is at the tangent point, and is easily shown to be (in this case) about 83 ft. The tangent point is 41·6 from B.

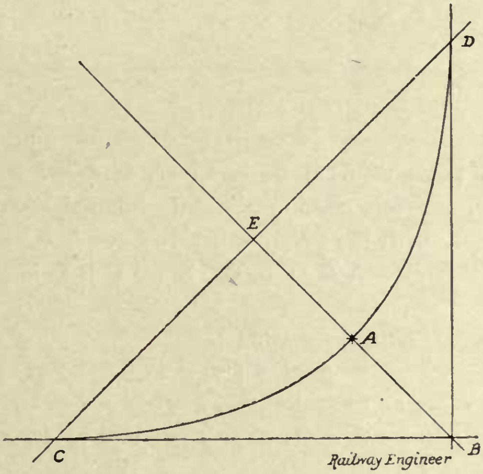


Fig. 27. Parabola.

Sine Curves.—

Another curve which has certain merits is the curve of sines. Rankin, in

Civil Engineering, gives the following directions for its construction (fig. 98) :—

On the intersecting line "select" the point A and make B C = B D = 2·75193 A B sec. ½ D B C, then D and C are the ends of the curve. D C is the circumference of a circle of which E A is the diameter; divide it into 180 parts corresponding to the degrees in a semi-circle, C E being 90°, and make the ordinates at each point of division equal to the sine of the angle corresponding to that point, then the curve C A D is the one required. The tangent point is 57·4 from B.

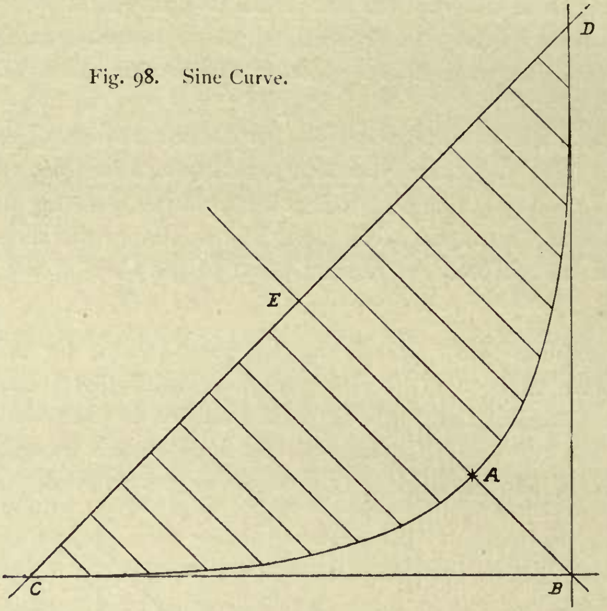


Fig. 98. Sine Curve.

Of course a sine curve could be constructed on any line parallel to D C, and still have its highest point at A; it is, however, essential that B C and B D be tangents at C and D, and this condition is only fulfilled when the proportions are as stated. Dealing only with the given data, we have A B = 14·7; A E = 1·75193 × A B = 25·8, and C E = π A E = 40·5. Since C B D is 90°, sec. ½ C B D = 1·414.

This is a sine curve, whose equation is

$$y = a \text{ sin. } c\, x.$$

Where c has such a value as to make $y = a$ when $c\,x = 90°$, x being in circular measure. Since at E, sin. $c\,x = 1$, $a = 25·8$; also at E, $x = 40·5$, hence $c = ·0388$.

The sharpest curvature is at A, where

$$\begin{aligned} \rho &= \text{A E tan.}^2\ \tfrac{1}{2}\ \text{C B D}, \\ &= \text{A E when C B D} = 90°, \\ &= 25·8. \end{aligned}$$

For values of x greater than C D, or 180°, sin. $c\,x$ will change in sign, and the extended curve becomes a sinusoid with points of inflexion at C and D, where the radius of curvature therefore becomes infinite. This is not good; there is obviously a waste of opportunity; the curve changes too slowly near the tangents, with a result that we have too sharp a curvature at the apex.

Lemniscate Curves.—

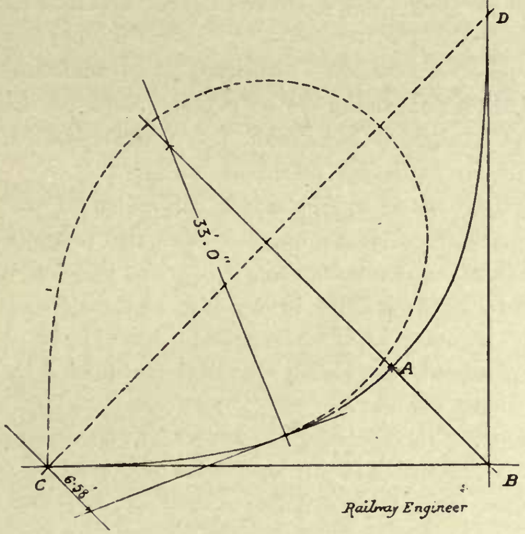
Another curve that has been suggested is the *lemniscate* or *lemniscata*: properly speaking this name is applied to a whole series of curves, but the particular one now in question is the *lemniscate* of Bernouilli. Its equation is

$$(x^2 + y^2)^2 = a^2 (x^2 - y^2)$$

which may be reduced to

$$r^2 = a^2 \cos.\ 2\ \theta.$$

This curve cannot be used in its complete form, as it returns upon itself, forming two leaf-like loops in shape like figure 8; but as a transition curve it has some interesting properties. Its radius of curvature varies inversely as its distance from the tangent point; *i.e.*, it is equal to some constant divided by that distance. In other words, when the car enters upon the curve, the twisting effect impressed upon it increases in direct proportion to the distance it has traversed since leaving the straight. Obviously this is the sort of effect desired.



Railway Engineer

Fig. 99. Lemniscata.

It will be found that 50 is a suitable value for a in the above polar equation, and since a portion only of the limniscata is required, we determine that the central portion of the complete curve shall be an arc of 33 ft. radius passing through the fixed point A as before. It will also be found convenient to transform the equation into the form

$$r^2 = a^2 \sin.\ 2\ \theta.$$

as the prime vector will then be a tangent to the curve at the origin C; one loop of the complete curve is shown by the dotted line in fig. 99. The readiest way of constructing the compound curve is to plot the first 30 ft. (or thereabouts) of the lemniscata on tracing paper to the same scale as the tramway plan, and then determine the point in it where the radius of curvature is 33 ft. This is done by the equation

$$\rho = \frac{a^2}{3\,r}$$

which making $\rho = 33$, gives a point on the curve about 25·3 from the origin. Next draw the normal at this point by making it perpendicular to the tangent (the sub-normal works out to a very inconvenient length, whereas the sub-tangent is only 6·58 ft. from this point); the centre of curvature and of the central arc will be on this line, 33 ft. from the curve. The tangent line through the origin, C, is then applied to one of the straights and the tracing slipped along until the 33 ft. arc passes through the fixed point A, and the elements of the curve are fixed throughout.

The sharpest radius of curvature on the lemniscata is when $r = a$, or $\rho = \frac{a^2}{3a} = \frac{a}{3} = 16·6$ ft., but this is of no consequence, since that part of the curve is not used. Since the origin C is a point of inflection of the complete curve, the radius is there infinite: this was pointed out as a defect in the curve of sines, but here the defect is of less consequence, as the curve "gets away" much more rapidly from the tangent. In the case taken, the tangent point will be about 46·6 ft. from the intersection B.

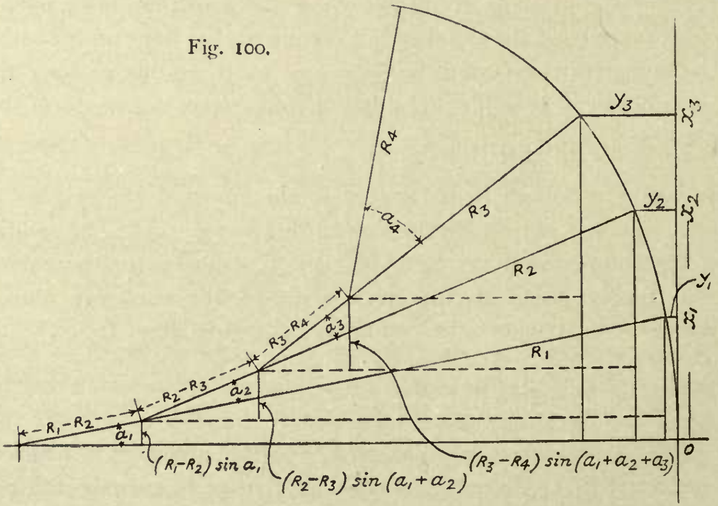
It may be useful to look at the question from a somewhat different point of view.

The transition curve is generally considered to be made up of a series of short circular arcs; the radius decreasing by successive steps as the distance from the tangent point on the straight is increased: the central parts of the curve being a substantial length of arc with the minimum radius.

The curve may be defined by the angle subtended at the centre by a chord of fixed length. Suppose for instance that near the tangent a chord, equal in length to the wheel base, subtended an angle of 1° to the centre of that part of the curve, it will subtend a greater angle in the next section if the radius of curvature be there shortened. In other words, the gradual increase in the speed of rotation will be obtained by gradually increasing the angle subtended by the fixed length of chord as it moves along the curve.

It is obvious that the three elements—length of chord, angle subtended at the centre, and length of radius—are all so connected, that if any two are given, the third is fixed likewise. It is not convenient to measure these small angles

Fig. 100.



either on a drawing board or on the ground, and it is therefore usual to reduce the curve to a series of points fixed by two measurements at right angles to each other. The way in which the required dimensions may be calculated is as follows:

Suppose the successive radii, R_1 — R_2 — R_3, &c., and the successive angles a_1 — a_2 — a_3, &c., are given. In the diagram, fig. 100, taking the tangent point o as the origin and the vertical tangent as the axis of x, we have by successive steps

$$x_1 = R_1 \text{ sin. } a_1$$

$$y_1 = R_1 - R_1 \text{ cos. } a_1.$$

Similarly the next point will be given by

$$x_2 = (R_1 - R_2) \text{ sin. } a_1 + R_2 \text{ sin. } (a_1 + a_2)$$

$$y_2 = R_1 - (R_1 - R_2) \text{ cos. } a_1 + R_2 \text{ cos. } (a_1 + a_2).$$

In the same way the diagram shows

$$x_3 = (R_1 - R_2) \text{ sin. } a_1 + (R_2 - R_3) \text{ sin. } (a_1 + a_2 + R_3 \text{ sin. } (a_1 + a_2 + a_3)$$

$$y_3 = R_1 - (R_1 - R_2) \text{ cos. } a_1 + (R_2 - R_3) \text{ cos. } (a_1 + a_2) + R_3 \text{ cos. } (a_1 + a_2 + a_3).$$

and so on for any number of points on the curve. The formula looks cumbersome, but the figures required are very easily worked out so long as the expressions are left in the shape as given, and the steps taken in their proper order.

The following is an example of a curve worked out on these principles:—

CURVE A.

Radius.	*Angle.*	*x.*	*y.*
358	0° 48′	4·998	·035
181	0 45	7·998	·101
121	0 57	10·003	·179
90	1 16	11·990	·295
72	1 35	13·972	·460
60	1 54	15·949	·685
52	2 13	17·938	·985
45	2 33	19·905	1·365
40	2 52	21·849	1·837
36	3 11	23·765	2·411

This curve is distorted or flattened for the first few feet from the tangent point, and the length of chord varies a little from 2 feet, so as to avoid fractions in the figures expressing the radius. If the origin were taken 4 feet along from the tangent point, the curve would be practically identical with the one given, the uniform length of chord previously referred to would be 2 feet, and the constant increment in the angle would be 0° 19′ at each step. Furthermore it will be noticed that the radius of curvature at any point is given by the equation

$$R = 720 \div (\text{chord} - 4)$$

the chord in this case being measured from the tangent point. Calling chord — 4 = r, we have

$$R = 720 \div r = 2160 \div 3\, r$$

$$= 46{\cdot}5^2 \div 3\, r$$

which shows that the curve is practically the lemniscata whose equation is

$$r^2 = 46{\cdot}5^2 \text{ sin. } 2\,\theta.$$

The Author prefers this way of expressing the curve: the coincidence is not exact, but the discrepancies are less than the variations which must occur in practically every case where rails are to be bent to any given curve, and it seems more rational to make the work approximate as near as possible to a true curve fulfilling the conditions laid down, than to make it approximate to another curve, which at the best is but an approximation.

A series of curves used by an eminent firm in laying out their track work is given in the following tables B, C, D and E. In B the increment of angle in each segment is 0° 42′, in C 0° 30′, in D 1° 0′, and in E 0° 42′, the same as in B, but the starting radius being doubled, the curve remains flatter throughout.

CURVE B.

Radius.	*Angle.*	*x.*	*y.*
210	0° 42′	2·565	0·015
105	1 24	5·130	0·078
70	2 6	7·692	0·219
52·5	2 48	10·245	0·469
42	3 30	12·780	0·860
35	4 12	15·283	1·420
CURVE C.			
300	0° 30′	2·618	0·011
150	1 00	5·235	0·057
100	1 30	7·851	0·160
75	2 00	10·463	0·342
60	2 30	13·065	0·627
50	3 00	15·651	1·036
42·5	3 30	18·187	1·587
37·5	4 00	20·703	2·309
CURVE D.			
300	1° 00′	5·236	0·046
150	2 00	10·468	0·229
100	3 00	15·688	0·639
75	4 00	20·871	1·368
60	5 00	25·982	2·501
50	6 00	30·959	4·118
40	7 00	35·403	6·143
CURVE E.			
420	0° 42′	5·131	0·031
210	1 24	10·261	0·157
140	2 6	15·384	0·439
105	2 48	20·490	0·939
84	3 30	25·561	1·720
70	4 12	30·567	2·839
60	4 54	35·469	4·352

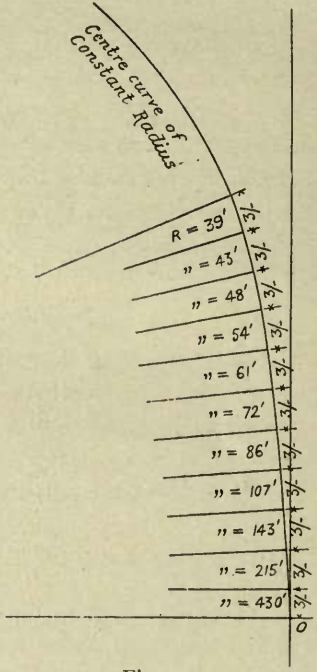


Fig. 101.

Another eminent firm uses the transition curve shown in fig. 101 in their special work. From the particulars given in the diagram, it is found that the increment of angle in a constant chord of 3 feet is 0° 24′ (the radius is evidently only stated to the nearest round figure), and from this the rectangular co-ordinates of the curve could be calculated by the formula given above. One or two trials on the slide rule, however, show that the curve differs quite insensibly from the lemniscata, whose equation is

$$r^2 = 62^2 \sin. 2\theta.$$

This expression contains everything essential about the curve, and it is to be preferred to the cumbersome formula required for rectangular co-ordinates.

Cubic Parabolic Curves.—

The cubic parabola $y = a x^3$ has been proposed as a transition curve, and was indeed one of the first curves used for the purpose. A value for *a* may generally be found which will give a more or less perfect approximation for a short length to any of the curves that have been mentioned, but there is no clear connection between the curvature at any point of such curve, and the distance of the point from the tangent. It is certainly more rational to use a curve in which these two essential elements are clearly connected together, in such a manner as to produce the desired effect.

In tramway work the central portion of each curve is an arc, having a radius as great as circumstances will admit of. The part of a transition curve therefore required in any case is only that portion between the tangent point and the arc of lowest radius exceeding that of the central arc.

Fig. 102 is a diagram showing roughly the relative differences between the curves described. They run so close together that it is impossible to carry them closer than about 10 feet to the tangent point on a small scale, and if they were full size they would practically all run into one at about 5 feet away from that point. Curve D and that of fig. 101 differ so little that the former one only has been shown.

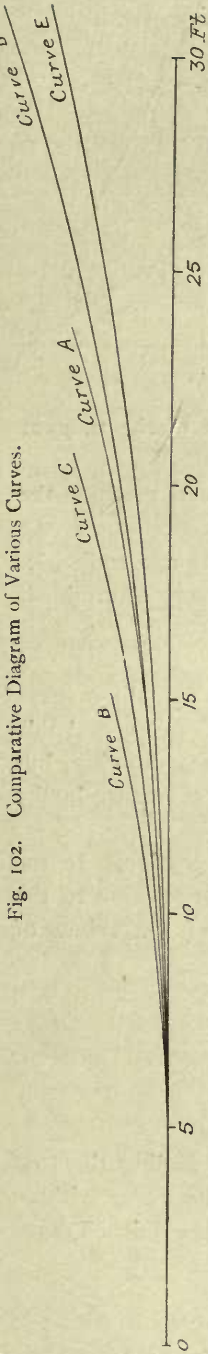


Fig. 102. Comparative Diagram of Various Curves.

The foregoing has all been based on the assumption that the tangent point where the curve commences is on an unbroken line; that is, that it is not a junction with another line. There was nothing then to prevent the curve starting very gradually with a radius of 200 to 400 feet. When the curve starts with a tramway point, however, this cannot be done, because, as has been pointed out in another place, it is not advisable to use a radius much more than about 100 feet at the heel of the point. This does not effect the construction of the transition curve, but that portion only of it is used where the radius is equal to or less than the radius to which the point is constructed.

In setting out a curve according to these principles, it is necessary to determine the actual position of the tangent point, *i.e.*, the distance of the commencement of the transition curve from the intersection of the two main lines of direction which the curve has to connect. The point of intersection is fixed on the ground by its surroundings, and everything else is fixed in reference to it. Unfortunately it is not a convenient point of reference in discussing the general principles on which the curve shall be laid out, and it is most convenient to leave it undetermined until these details have been settled.

Fig. 103.

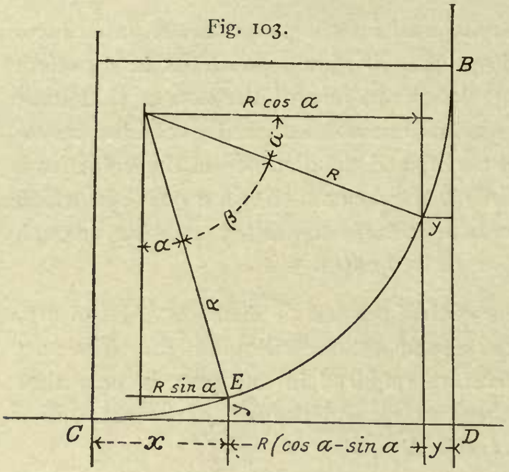
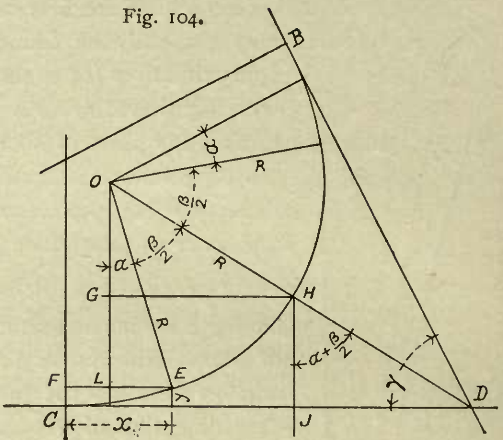


Fig. 104.



When the two main lines meet at right angles, the position of the tangent point may be found as follows :—

In fig. 103, let the transition curve extend from C to E, and produce the tangent to meet the other one in D; let a be the total angle of deflection due to the transition curve, and β be the central section of constant curvature and radius R. Let x and y be the co-ordinates of the curve at the point E as already determined. Then from the figure it is evident that the distance required is C D $= x + y + \text{R} (\cos a - \sin a)$.

When the angle of intersection is not a right angle, as in fig. 104, the process is not so simple; we must determine γ, the angle of intersection. In general this will be measured with greater accuracy on the ground than from any drawing, but in any case, when its value is ascertained, the angle of constant curvature in the centre will be $\beta = 180 - (2\,a + \gamma)$.

The next step is to find H, the middle point of the central section. In the figure, draw H G and E F parallel to, and H J, and O L perpendicular to the tangent C D, then the distance required is evidently the sum of the values of F L, G H, and J D.

From the figure, it follows that

$$\text{F L} = x - \text{R} \sin a$$
$$\text{G H} = \text{R} \sin (a + \tfrac{1}{2}\beta)$$
$$\text{J D} = \text{H J} \tan (a + \tfrac{1}{2}\beta)$$

where H J $= y + \text{R} \cos a - \text{R} \cos (a + \tfrac{1}{2}\beta)$.

These values should be calculated according to the formula; scaling them off a plan may be quite near enough to enable a car to traverse the curve without leaving the metals, but it is not near enough in general to ensure the finished curve being of the dimensions and radii designed.

See also Appendix No. 1.

Wheel-base and Gauge.—

In traversing a curve the car wheels are subjected to a strong twisting stress, its amount depending upon the radius of curve, the length of fixed wheel-base,

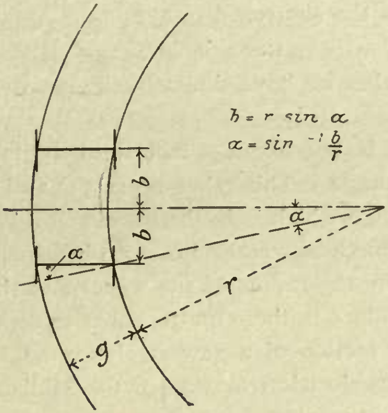


Fig. 105.

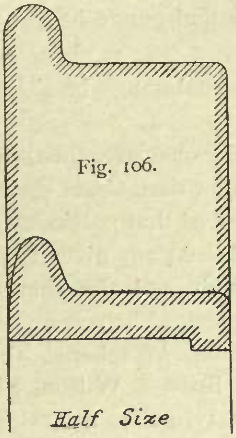


Fig. 106.

and several other items which are not constant or essential factors, such as shape and state of the wheel flanges, the size of the wheels, width of gauge, width of groove, &c.

In passing round a curve a four-wheeled truck always tends to set itself so that the trailing axle is radial; if it were not for the restraint imposed by the groove the trailing wheels would fall inside the curve. That is to say, the action of the curve is to push the leading axle inwards and the trailing axle outwards, and the relative stresses which the grooves must exercise to keep the two sets of wheels on their proper tracks will depend upon the length of wheel-base. This may be explained to some extent in another way. In passing round the curve the car has to be rotated round a vertical axis. Apart from centrifugal force, which can only be effective at higher speeds than are possible on a tramway curve, this rotation can only be accomplished by pushing the leading axle inwards and the trailing axle outwards.

The gauge of the tramway is the shortest distance between the outsides of the two grooves measured in the direction perpendicular to them. On a curve this perpendicular direction must pass through the centre, and at any point on the curve the two axles of a truck will be parallel to the radial line midway between them, or as near thereto as the restraint imposed by the grooves will admit; any oblique distance between two parallel curves must be greater than the radial distance, and therefore the gauge measurements on such a curve should be something less than the gauge distance on a straight track. The proper amount of this shortening obviously depends upon the length of the fixed wheel-base to be used as well as upon the radius of the curve, and its value may be computed as follows :—

In fig. 105 the wheel-base is assumed to be 6 feet, so that $b = 3$ feet,

$$\text{then } 3 \div r = \sin. a$$

and the shortened gauge will evidently be $= g \cos. a$

on a 40 ft. curve we shall therefore have

$$\sin. a = 3 \div 40 \text{ so } a = 4^\circ\ 18'\ 4''$$

if the normal gauge be 3′ 6″ or 42 inches the shortened gauge

$$g^1 = 42 \cos. 4^\circ\ 18'\ 4'' = 41{\cdot}882 \text{ inches}$$

if the normal gauge be 4′ 8½″ = 56·5 inches we have similarly

$$g^1 = 56{\cdot}5 \cos. a = 56{\cdot}341 \text{ inches.}$$

In the one case, then, the rails should be laid about ·1 inch tight to gauge, and in the other case about $\frac{3}{16}$ inch tight to gauge. This takes no account of the size and shape of that portion of the wheel flange which is in the groove and below the rail level. At any given instant this is a piece of metal 7 ins. or 8 ins. long, about ⅝ in. thick, and of a shape determined by the radius of the wheel and the shape of its flange. There is no recognised standard in these matters, but as an example fig. 106 may be taken. This shows the section of a new steel tyre as made by Askham Bros. & Wilson, Sheffield, for an electric tramway in the Midlands, and the same tyre after a service of about 40,000 miles.

Fig. 107 shows the actual shape of the piece lying in the groove when the tyre was new, and fig. 108 the shape due to the worn tyre; it is rather shorter than fig. 107 because the wheel is now of a smaller diameter. The peak at A is due to the rounding off of the flange into the wheel tread and might have been omitted, as in practice it is compensated for by the rounding of the edge of the rail.

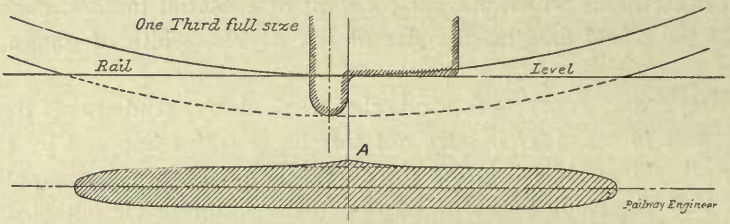


Fig. 107. New Tyre.

In passing round a curve this piece of metal is twisted obliquely in the groove, and there must be sufficient width in that groove to admit of the obliquity due to the angle a in fig. 105. If this width be insufficient the wheel will be lifted off its tread, and will probably leave the metals, besides the risk of breaking the flange owing to it having to carry in a very disadvantageous manner the whole weight of this corner of the car. It must be remembered that the piece of metal shown in fig. 107 or 108 is not a solid piece sliding horizontally in the groove, but is perpetually changing as the wheel revolves; its forward end is moving vertically downwards, and the side in close contact with the outside of the groove is always tending to mount upwards and lift the wheel out of its proper place.

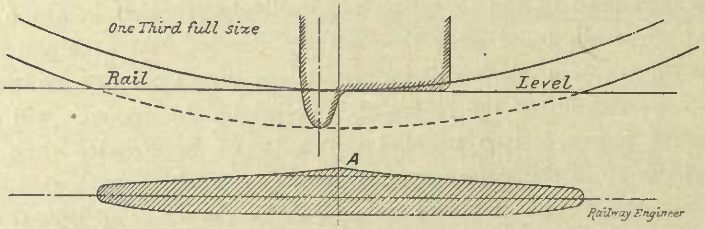


Fig. 108. Worn Tyre.

The effect of raising the guard flange of the inside rail above the normal level will be apparent by a consideration of figs. 107 and 108. It will increase the length of the block of metal in the groove and thereby add to the obstruction in rounding a curve, unless at the same time the width of that groove be proportionately increased. A low guard on that rail will shorten the length of the active part of the flange, and though it may diminish the obstruction in rounding a curve, it will at the same time increase the risk of the wheel leaving the track. A low guard on the outside rail will have the effect of diminishing the obstruction without increasing the risk referred to, and the best practice appears to be to use a low guard on the outer rail with a normal width of groove, and on the inside rail to use a guard flush with the tread, and at the same time to widen the groove. Unless this groove is widened very considerably nothing is gained by raising its guard above the normal level, and the high guard is decidedly objectionable to vehicles of the ordinary type.

When curves occur on a double line their effect upon the overhang of the car becomes important, and special precautions may have to be taken in laying out such double curves so as to maintain the 15 ins. clearance required by the Board of Trade. As is the case in many other items of track construction, the type of car to be used is one of the principal factors in considering this question. In cars of the bogie type the overhang will in general be increased both on the inside and the outside of the curve, whereas in cars of a fixed wheel base the increase on the inside is practically nothing, but on the outside may be very considerable. When cars of both types are, or may be, in use, as often happens, this question of increased overhang is of still greater importance.

As an illustration, the car shown in rough outline in fig. 109 may be taken—it is 33 ft. long, 6 ft. wide, with a wheel-base of 19 ft. between pivots of bogies.

On a straight track of 3 ft. 6 ins. gauge the normal overhang beyond the gauge lines will be 1 ft. 3 ins. In fig. 109 it is seen that on a 40 ft. curve it will be increased to about 2 ft. 3 ins. on the inside and to about 3 ft. on the outside, making the total width of space required 8 ft. 9 ins., instead of the 6 ft. required for a straight track, and the width of middleway on the curve will have to be modified accordingly.

In fig. 109 the lines A A A and B B B show the space required by the cars in passing round the inner curve of 40 ft. radius; the dotted line C C shows what the outer limit would be, as determined by the forward end of the car in entering the curve and the trailing end of the car in leaving the curve; but the full line B B B shows how this limit is increased when the centre pivots of both bogies are on the curve—the central parts of the limits are arcs of circles—the inner one touching the centre of the car and the outer one passing through the extreme tips of the platforms. At the ends these arcs blend into the limits due to the straight track by two transition curves, which are best determined on the plan by sliding a plan of the car round the curve and marking points upon them, as may be necessary to fix their position. When this has been done for the inner curve the position of the centre line of the outer track will then be fixed by slipping the plan of the car

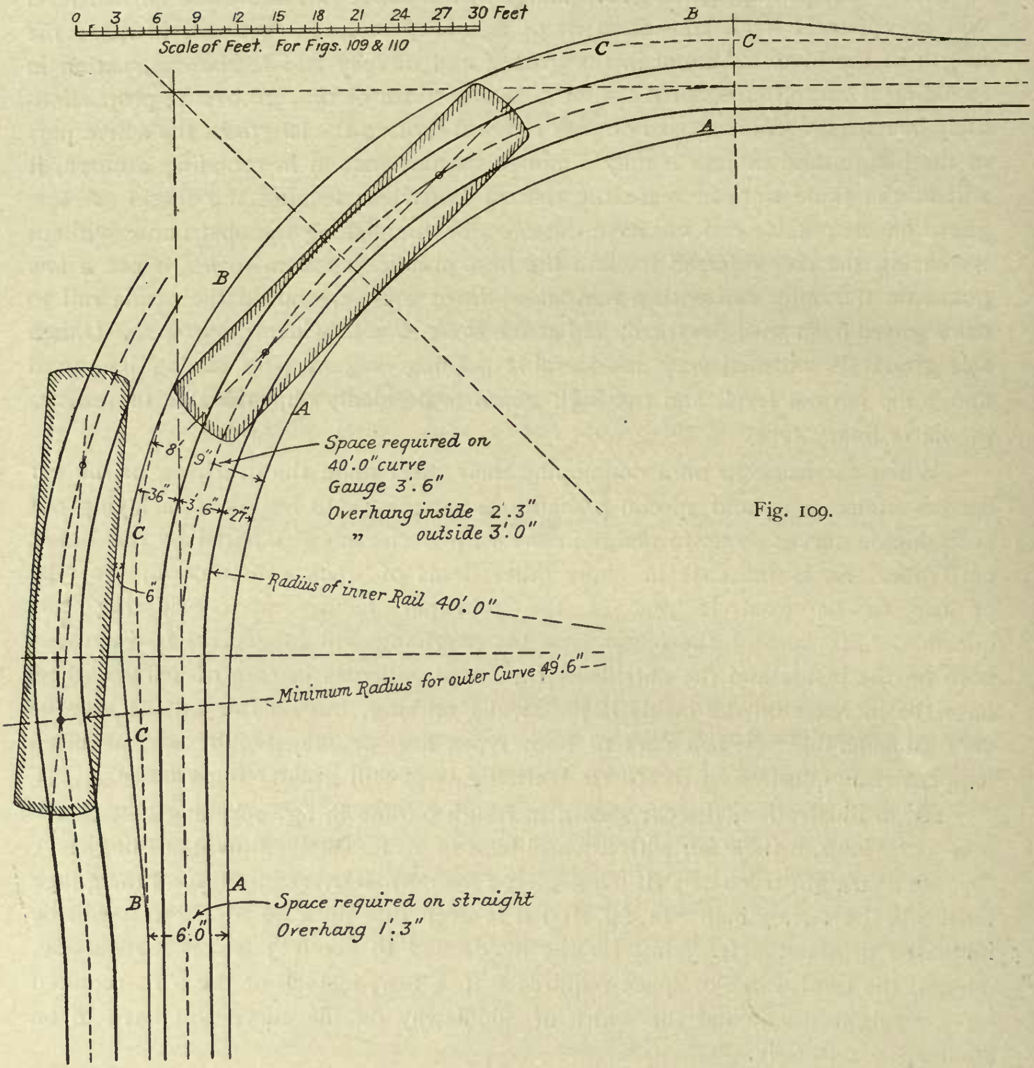

0 3 6 9 12 15 18 21 24 27 30 Feet
Scale of Feet. For Figs. 109 & 110
B
C
C
A
B
A
8'
9"
36"
3'.6"
27"
C
6"
C
B
A
Space required on
40'.0" curve
Gauge 3'.6"
Overhang inside 2'.3"
" outside 3'.0"
Radius of inner Rail 40'.0"
Minimum Radius for outer Curve 49'.6"
Space required on straight
Overhang 1'.3"
6'.0

Fig. 109.

round the outside, giving everywhere the required clearance (here taken as six inches), and pricking through the corresponding positions of the bogie pivots—these will be points on the centre line of the outer curve; and it will be seen that when the inner curve is taken as a plain arc commencing upon the tangent with the minimum radius, the result will be that the outer curve will run into the straight tract with an objectionable reflex curve; this can be avoided by laying out the outer track first and then finding points on the centre line of the inner curve afterwards, in the manner just described and as shown in fig. 110.

The use of the transition curves described elsewhere is not affected by these considerations, but it is rather more troublesome to find what would be a suitable curve on the inside, after the outer curve has been fixed. No general rule can be given, but each case must be determined by the data of cars, &c., assumed in

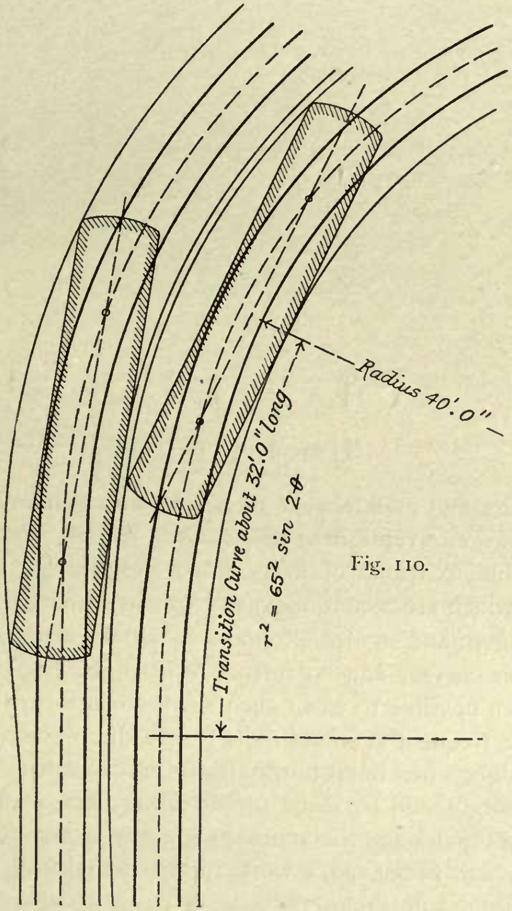


Fig. 110.

laying out the work. It is, however, advisable to use a curve capable of simple expression and elastic in its application, and nothing better than the lemniscata can be suggested. In the example shown on fig. 110, for instance, it is easy to ascertain that some such value as 65 for a in the equation

$$r^2 = a^2 \sin. 2\theta$$

is likely to result in a suitable curve.

The modifications due to cars with a fixed wheel-base present no difficulty, since the centre of the car may be assumed to be always over the centre line of the track, and there will be no increase in the overhang on either the inside or outside curve; it will be therefore only necessary to provide for the increased overhang on the outside of the inner curve, and this is easily done according to the principles illustrated in fig. 110

CHAPTER X.

TEMPORARY TRACKS.

THE work of repairs and maintenance on a tramway system is expected to go on without causing any interruption to the tramway traffic, and with as little inconvenience as possible to traffic of every other description. In the casual small repairs to paving which are a continuous ever-present necessity on an average line, this is easily arranged; and so also in repairs to metals, changing points, crossings, a few odd rails on curves, and so forth. With light traffic, say at 10 minutes intervals, it is often possible to effect such small changes in the metals in the day-time: with a more frequent service this is practically impossible, and the changes must be made at night when the tramway traffic is suspended. In an ideal tramway system arrangements would be made for diverting such traffic into other streets; but convenience of repairs and maintenance is never an item of consideration when lines are laid out, and hence night work for the platelaying department becomes unavoidable. The final finishing, packing of track and restoration of pavements can go on in daylight without disturbing the traffic the lines are designed for: traffic of other sorts is a secondary matter.

But night work *per se* is not profitable: it always tends to become deficient in quality or quantity, and generally in both, and is only really justified when it is the only possible means of maintaining the traffic. The judicious use of a temporary track may often avoid the necessity of such work, and what is of still more importance, it may permit of the work being better done, inasmuch as the traffic may be kept off until the cement and concrete used have had a chance to properly set. Furthermore, a temporary track may enable sewerage or other underground works to be carried out without interfering with the traffic. In every tramway Act the Local Authority retains power to stop up or remove the tramway in such cases when necessity arises, and, therefore, power is taken in the Act for the construction of such tracks, either in the same or in adjacent streets, and the exercise of such power will frequently be of advantage to both parties concerned.

The most usual type of rail used on temporary tracks in the past is perhaps the now practically obsolete "box rail," as shown in fig. 111. This was a favourite rail on the old horse tramways, and when spiked to a shallow longitudinal

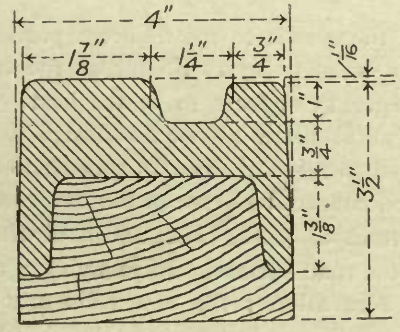


Fig. 111.

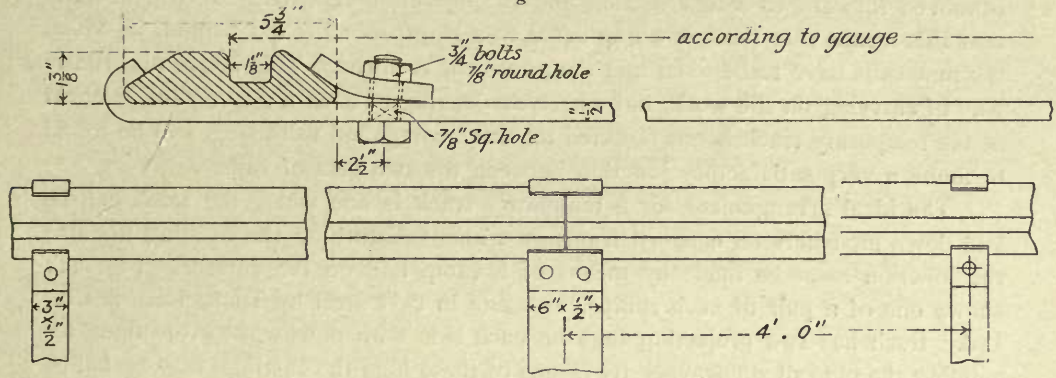


Fig. 112. Temporary Track.

sleeper was quite sufficient for temporary purposes when there was nothing but light horse cars to be dealt with.

It, however, is not good enough for the heavier cars used with mechanical traction, and as it is doubtful if new rails of this section could be obtained if they were wanted it is unnecessary to discuss the details connected with it.

The best rail for a temporary track is undoubtedly the section shown in fig. 112 and others, which is rolled for this special purpose. It is practically 6 ins. wide on the base, and only 1 3/8 ins. high, and has, therefore, no tendency to tilt over under any conditions of traffic. The rails are connected together only by the flat tie-bars shown in the drawing, and which should be spaced about 4 ft. apart, those of double width serving as jointing plates. The joints may be placed opposite one another, but it stiffens the track to keep them about the space of two tie-bars apart.

This track is laid on the road surface, paved or macadam, the rails being levelled and bedded on loose gravel, "shingle," granite, or slag chippings. Rounded gravel is not good, as it is so easily shaken out of its place: the best packing is crushed granite or slag chippings, which may be further mixed with sand. When this is properly packed under the rails, with a liberal allowance of loose material outside to back it up, it requires very little attention to keep the track in satisfactory running condition, except, perhaps, after heavy storms, or in persistently wet weather. These conditions, however, are apt to cause trouble or tracks that are not designedly of a temporary character.

The connections of these rails to the adjacent parts of the permanent track may be arranged for in various ways. So far as the tramway running is concerned, that shown in fig. 113 appears to be the best. It consists of a pair of castings, formed to act as fishplates at one end, fitted to the permanent rail, and at the other end arranged to serve at once as a bed and a clip for the temporary rail. This makes a good connection between the two rails, and from the point of junction the temporary track of course rises, and is diverted to the one side or the other to its position on the road surface. In re-laying a tramway, this will be the road-side clear of the excavations: the new rails are laid, and the pavement restored, throughout the section the temporary track has left clear, when the track is moved forward to a new section and the operation repeated. It will be seen that this means that there is a gap equal to a length of rails left behind, in which the new rails have to be fixed and the pavement restored. This is not an orderly way of carrying on the work, but where the leaving of such a gap on the removal of the temporary track is not objected to, these compound fish-plates will be found to make a very satisfactory junction between the two sets of rails.

The ideal arrangement for a temporary track is one where the track can be laid down anywhere on a paved tramway without disturbing the existing metals: the junction must be made by means of a ramp laid on the surface. Fig. 114 shows one of a pair of such ramps, as made in cast steel by Dick, Kerr & Co., Ltd. Each has two projecting lugs on each side with downward projections for clipping the old rail sideways. By means of these lugs the castings may be bolted down to a tie plate slipped under the rail.

Fig. 115 shows another form of ramp, made by planing away parts of the flat rail shown on fig. 112. Holes are made in the paving, and a piece of 3 ins. × ⅝ in. flat bar pushed under the rail to take the heads of the bolts used for fixing the ramp in position. Pins and wedges not shown in the figure serve to keep the ramp in lateral adjustment, and all hollow spaces between the ramp and the rails and paving are filled in as solidly as may be by the usual packing.

A temporary track is more usually required to connect the two roads of a double line, so that the traffic may be diverted from the one to the other. As this one has to take the traffic in both directions, points must be introduced to effect its junctions with the temporary track. These points might be made part of the ramp, but it is better to leave this intact, and place the point behind it.

Figs. 116 and 117 show a suitable pair of points with a left-hand deflection;

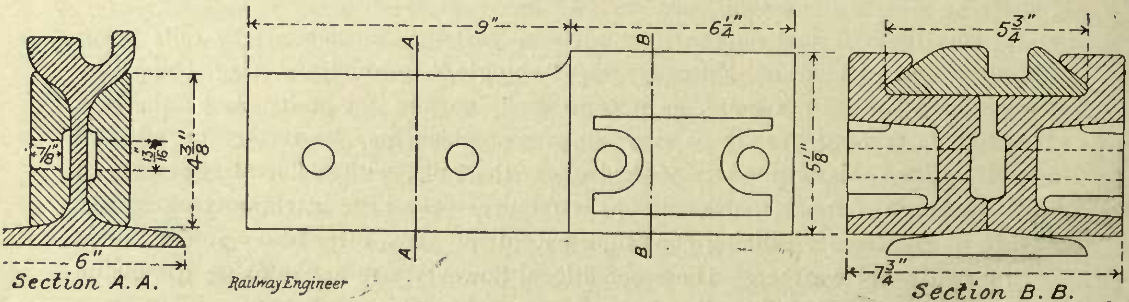


Fig. 113. Special Fish Plates.

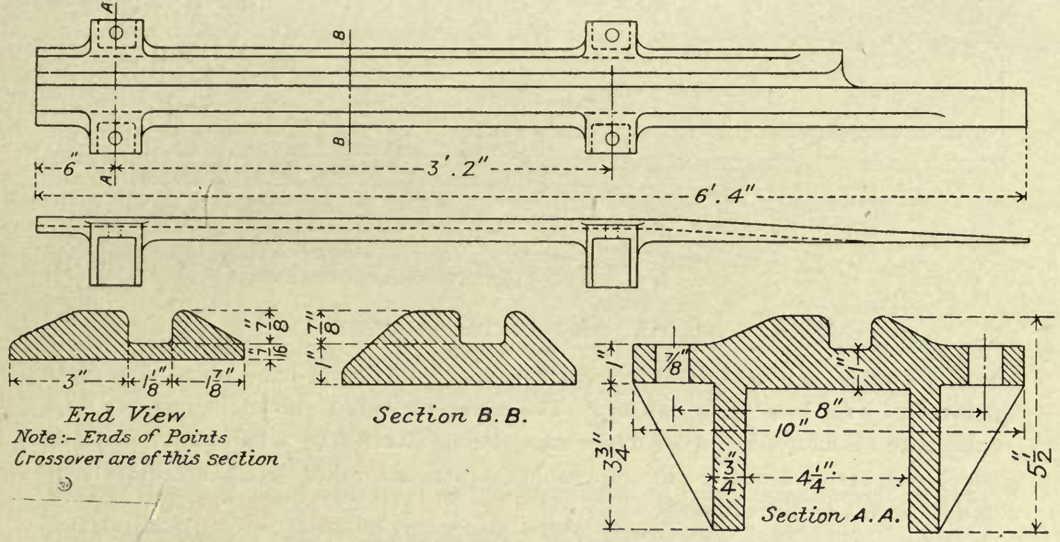


Fig. 114. Ramp.

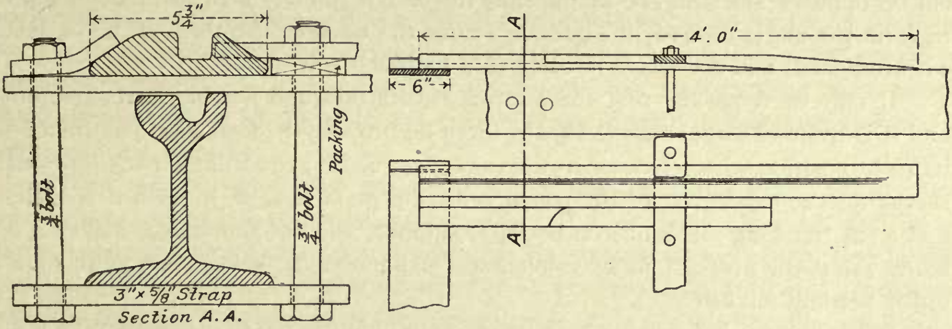


Fig. 115. Ramp.

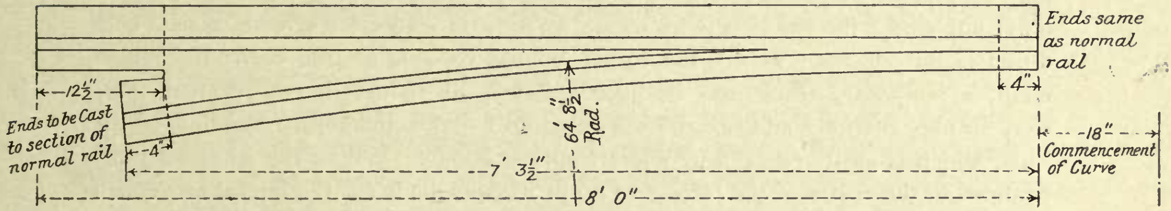


Fig. 116. Right Hand Open Point, Left Hand Throw.

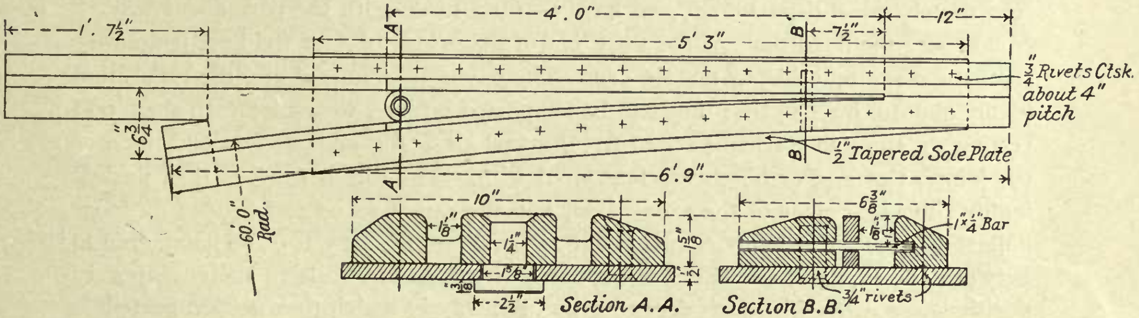
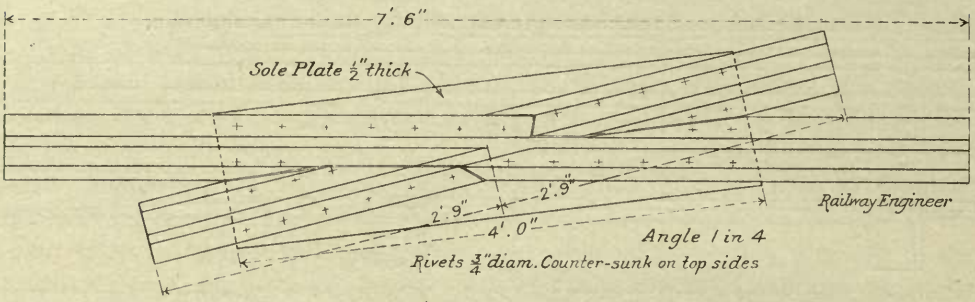


Fig. 117. Left Hand Movable Point, Left Hand Throw.



Railway Engineer

Fig. 118. Crossing for Temporary Track.

but, of course, the same construction will apply to a right-hand also. The open point, fig. 116, is a plain casting. The moveable point shown in fig. 117 is a composite structure, the fixed upper parts being rivetted to a half-inch sole-plate, which also forms a bed for the moveable tongue : the other details are quite sufficiently shown on the drawing.

The crossings are best built out of rails, as shown in fig. 118, recesses being cut on opposite sides on one of the rails to receive suitably shaped junction pieces to form the angle desired, the groove across the head of the through plate being cut afterwards and the whole rivetted to a half-inch sole-plate.

It may be remarked that the ramp is rather thin and flexible at its free end, and it is quite essential that it should there be properly bedded and maintained in its right position with reference to the rails underneath : the shingle packing, which serves for the other part of the track, is hardly good enough in such a situation, and a rust packing made of iron borings, sulphur, and sal-ammoniac, makes a far better joint, the proportions of sulphur and sal-ammoniac being such as to give a quick setting mixture.

It is obvious that where horse or steam traction is used, the temporary track may be laid with special reference to the requirements of the road and its traffic only; but where the traction is by means of an overhead electric wire, a new condition is introduced. Where the trolley pole is capable of free horizontal movement, a temporary track may be used as freely as though horse or steam cars were in use, the only additional work required being a temporary bonding of the rails, which is easily effected by short Neptune bonds. Where the wire is rigidly confined to the centre of the track and no provisions made for the lateral movement of the trolley arm difficulties will arise. These, however, are matters which concern the electrical department, and have nothing to do with the permanent way.

Where the conditions of the work and traffic admit, one of the best temporary tracks is made by utilising the old one. The paving is removed and the rails lifted bodily about 9 ins., so that they can be supported on bars thrust beneath them and resting on the undisturbed pavement. Except as to the joint at one end none of the joints, tie-bars, or bonds are interfered with. The raised track is then pushed bodily sideways, clear of the excavation, and the rails packed and bedded on loose ballast as required. Wooden struts cut to exact lengths may then be hammered in between the tie-bars, or other means taken to stiffen the rails in their temporary position, but as to this much depends upon the way in which they are supported.

CHAPTER XI.

Track Drains and Drainage.

Water has a peculiarly destructive influence upon a tramway subjected to heavy traffic. Such a line must be frequently under repair, and a necessity for a large proportion of these repairs may frequently be traced to the presence of water under the rails and paving. Every effort is justifiable to cut off as far as possible its source of supply on the surface. Apart from its destructive effects, surface drainage is desirable in promoting the cleanliness of the track : a dirty road means extra wear and tear to the rails and rolling stock, and it furthermore entails an extra expense in power.

When rain or water from any other source falls upon the track, the greater part of it soon gets into the grooves; once there, it runs freely down hill until it is turned aside and again caused to spread over the surface by any obstruction in the groove. In the absence of this obstruction it would run on until it spread at a swag in the rails, and consequently drainage should be provided at all such points in any case, and the more frequently the drains are spaced along an incline the less liability there will be for grit and road detritus to form any local obstruction in the groove.

It is difficult to say exactly what this destructive action of water is due to; perhaps some of it is due to its dissolving power, for water has the property of dissolving to some extent nearly every element in nature, but there can be no mistake about its mechanical action, that is, its power of swilling and washing away all the sand and smaller particles of the concrete and bedding under its influence : this makes the mass become porous in texture, giving more room for water to accumulate, and greater facilities for it to exert its disintegrating powers. The great difficulty under heavy traffic is to keep the rails and pavement solidly bedded; they are put into vibration by every passing car, and this vibration can only result in setting the water below the surface into motion, and it is to the fact that the water is thus set into motion that the greater part of its destructive influences must be attributed.

A rail drain must dispose of the water which gets into the groove.

Fig. 119 shows how this is effected by Dawson's Drain Rail as made by Askham Bros. & Wilson, Ltd., fig. 120 being a cross section of the same : it is a

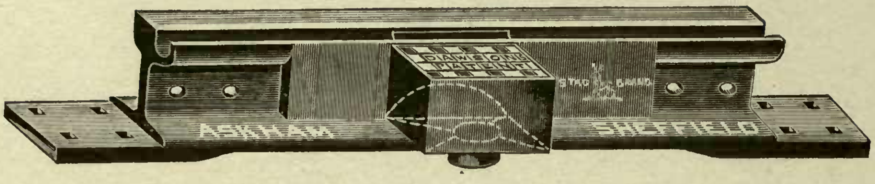


Fig. 119. Dawson's Drain Rail.

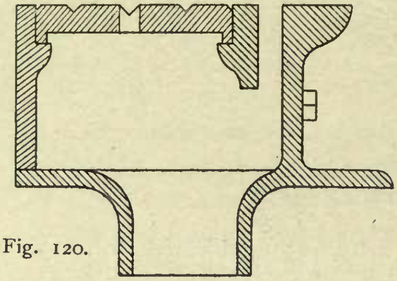


Fig. 120.

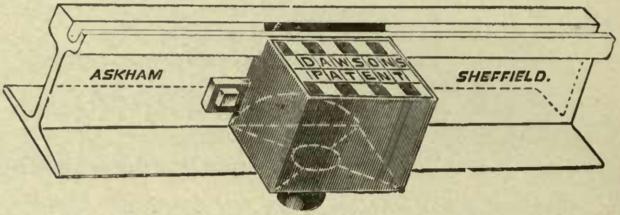


Fig. 121.

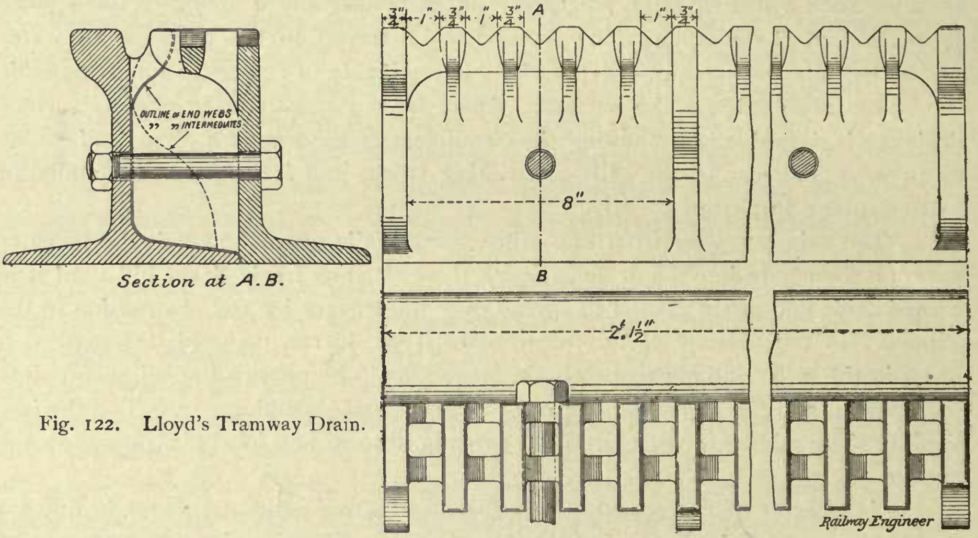


Fig. 122. Lloyd's Tramway Drain.

casting formed to the ordinary section of the rail, and takes the place of the ordinary running rail for a length of from 6 ft. to 8 ft., and may be either straight or curved as circumstances require; it is connected to the rails at each end by fish-plates in the usual manner. The small dirt box at the side affords a means of access for cleaning out, or if necessary for flushing.

There is an objection to using the self-contained casting; it must be only a few feet in length, and thereby two joints in the road are brought rather too close together. Fig. 121 shows a modification whereby this weakness in the track is avoided. The bottom of the groove of the ordinary running rail is cut away at the place where the drain is required, and a cast box with a removable lid and an outlet into the drain below is bolted on to the side of the rail; the connections to the drains below will be arranged precisely as in the older pattern.

Fig. 122 shows another form of drain, introduced by F. H. Lloyd & Co., Ltd.,

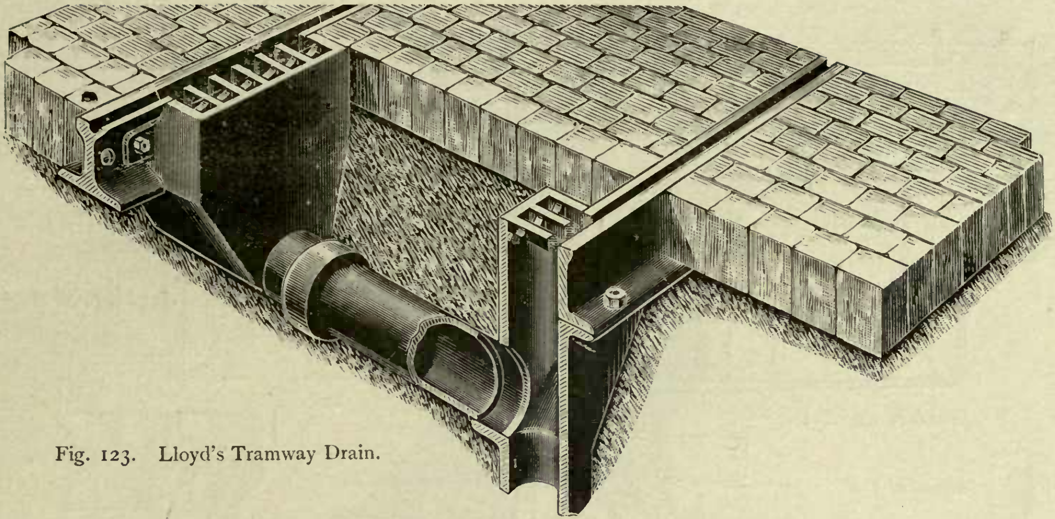


Fig. 123. Lloyd's Tramway Drain.

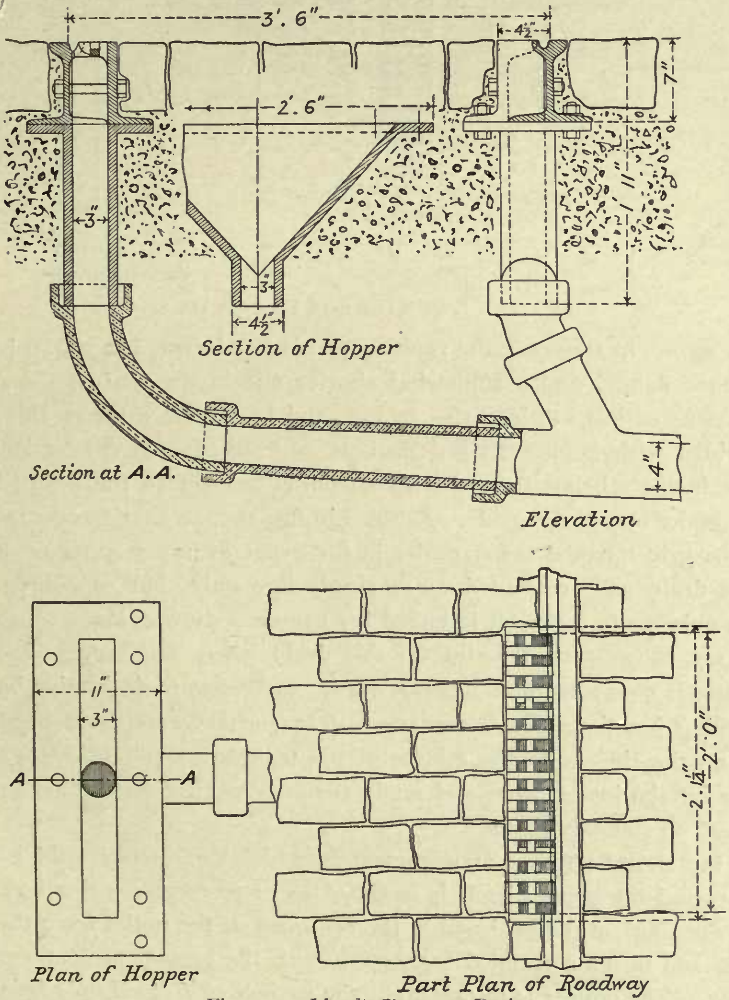


Fig. 124. Lloyd's Tramway Drain.

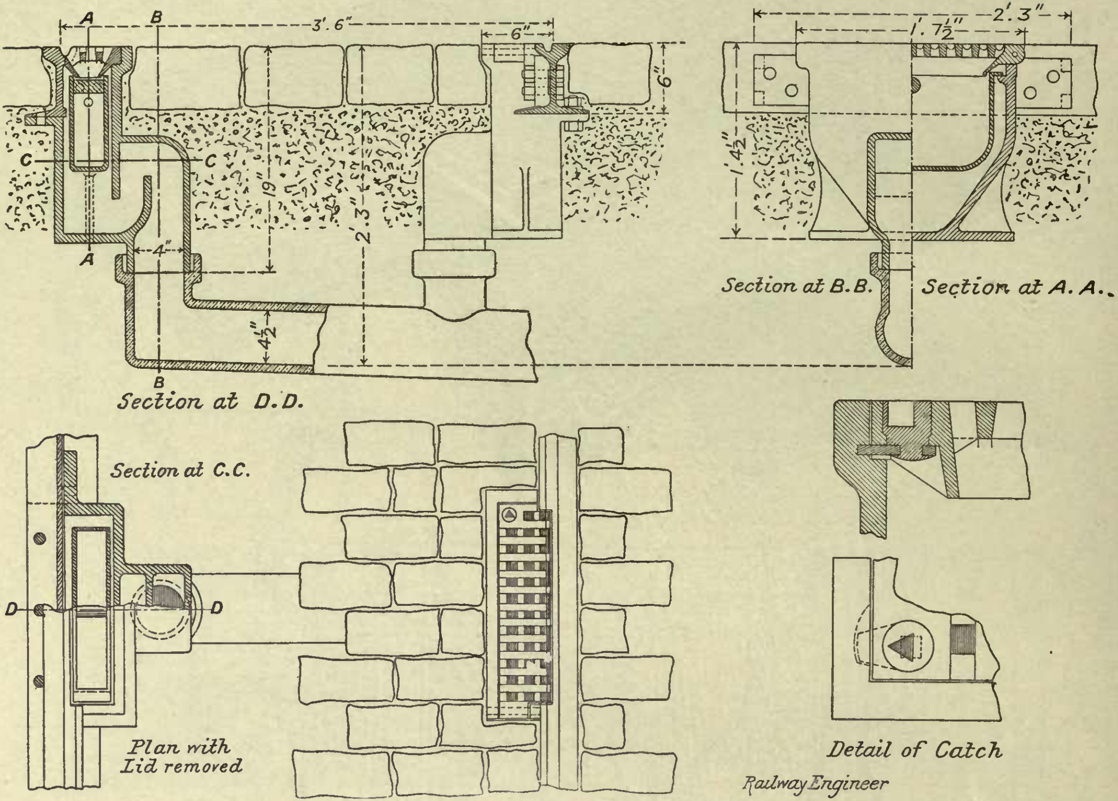


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Fig. 125. Lloyd's Improved Tramway Drain.

some time ago. In this case the running rail is left intact, but a gap is cut away in the groove flange, and a somewhat shorter one in the foot of the rail below, a grid-shaped casting fits into this recess, and in the later forms this drain has been provided with hopper shaped pockets with transverse connections below—one of the hoppers being formed with an outlet leading to the drain; this outlet is directly under one of the grids, as shown in fig. 123, so that a rod can be pushed through the grid into the sewer outlet in the event of any stoppage. This figure shows the drain as constructed for a single line only, but of course the same remarks would apply for a set intended for use on a double line.

Fig. 124 shows a modification of this drain where the hoppers are all alike, and each one is connected directly with a 4 in. earthenware drain pipe below, these again forming junctions with a transverse 6 in. earthenware drain opening into a catch pit on the side or in the middle of the tramway track. Arrangements are here made for the interception and ready removal of all detritus that may find its way through the surface grids.

Fig. 125 shows another arrangement in which the surface grid is hinged to the hopper, and the hopper itself is modified so as to receive a dirt box extending under the openings in the grid and in the rail groove; the outlet from the hopper is at the side and forms a trapped connection with the system of earthenware drain pipes below. The hopper is of cast iron, the surface grid itself only being made of the more expensive material steel, and this is provided with a simple latch arrangement, as on certain forms of manhole covers, to prevent mischievous interference.

Fig. 126 illustrates the track-drain introduced by the Ames Crosta Engineering Co., Nottingham. The casting is bolted to the side of the rail as in some of the other devices, and the bottom of the groove is cut away for a length of about 12 ins., either continuously or as a series of slots. The catch-pit acts as a sewer gas trap, and the outlet to drain is freely exposed when the lid is removed.

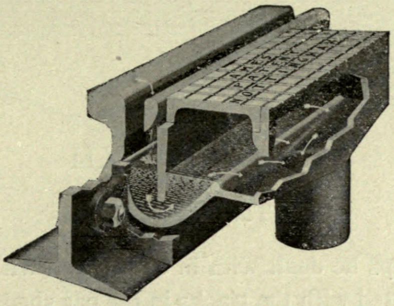


Fig. 126. Ames Crosta Tramway Drain.

* * *

CHAPTER XII.

TRAVERSERS.

A TRAVERSER may perhaps be dealt with in connection with the permanent way, as it is so intimately connected with the tracks in the car shed. Sometimes a traverser is constructed to run in a transverse pit about 18 ins. deep, its top platform being level with the general floor of the shed. This pit is a very objectionable feature; it may facilitate the construction of a substantial traversing carriage, but the space it occupies is always quite useless for any other purpose, and the pit must therefore be placed at the remote end of the shed—this is not always the most convenient place for a traverser.

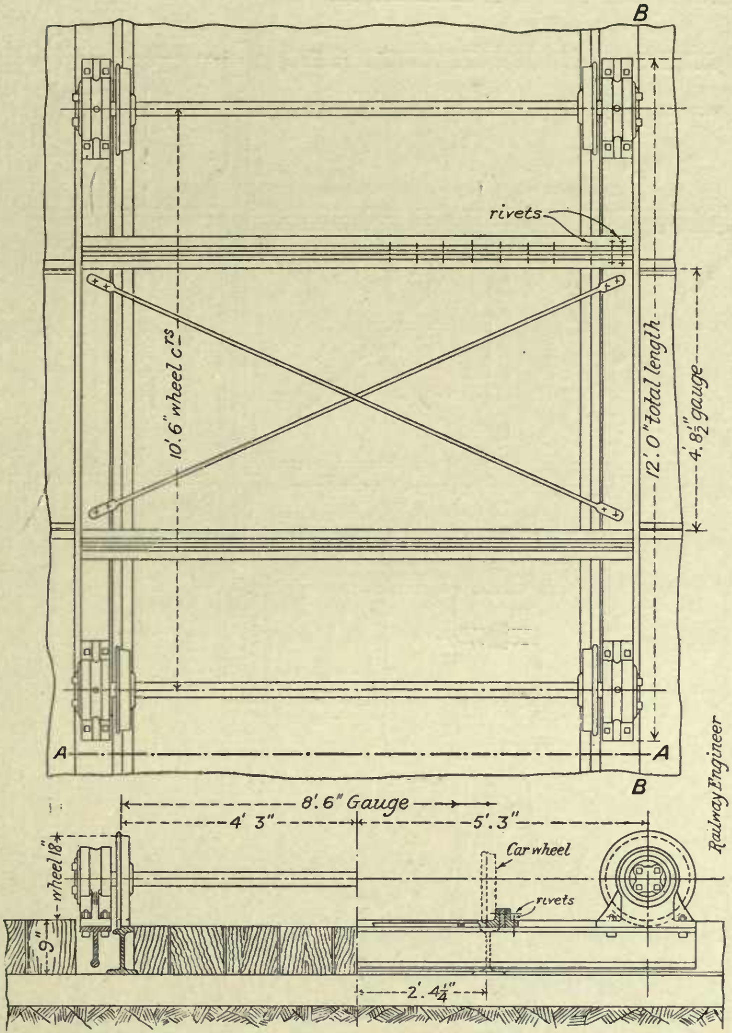
Lorain Steel Co.'s Traverser.—

Fig. 127 shows a traverser as made by the Lorain Steel Co., in which the pit is practically abolished, being only about an inch deep, so that the general floor of the shed is hardly interfered with, except that the track rails cannot be continued across the space occupied by the traverser.

The main frame of the carriage consists of two bulb tee irons, the table being upwards, which are suspended from the axles of the traverser wheels; the rails intended to carry the car are rivetted to the tables of these bulb irons, the wheels running on the lower side of the angles so that the upper table of the bulb iron is practically level with the bottom of the groove of the ordinary track rail; the other details of the structure are clearly shown in the figure. The most objectionable feature about the traverser appears to be the gap occupied by the bulb tee iron, which is about 6 ins. wide and 9 ins. deep, but this is far better than the 18 ins. pit previously referred to.

Wharton & Co.'s Traverser.—

Fig. 128 shows a traverser as constructed by Wharton & Co., in which the pit is entirely done away with and the rails carrying the car are lifted quite clear of the general surface of the car shed. This means that an inclined approach has to be fitted at each end of the traverser to connect its carrying rail with the general track. If the traverser is placed at the end of the shed, of course, one such approach is enough, but in any other position these inclines must be provided on each side of the travelling carriage, as shown in the drawing; these inclines may



Half Section at A.A. *Half Section at B.B.*

Fig. 127. The Lorain Steel Co.'s Standard Transfer Table.

be lifted into a vertical position by means of a system of levers, when the traverser is not in use : the transverse motion of the carriage itself is provided for by a worm wheel on one of the axles.

Glasgow Corporation's Traverser.—

Fig. 129 shows another traverser as used in the Glasgow Corporation Tramway sheds, and designed by the Corporation engineer—this is independent of any pit, and may therefore be placed in the most convenient position in the car sheds or repairing shops. It is provided with ramps at each end which can be lifted out of the way when not in use, and it will be seen that each pair is provided with a balance spring which can be adjusted to keep the point of the ramp just clear of the tracks and general surface of the floor. This traverser is of very simple construction, but it evidently contains all the essential features necessary to such a structure,

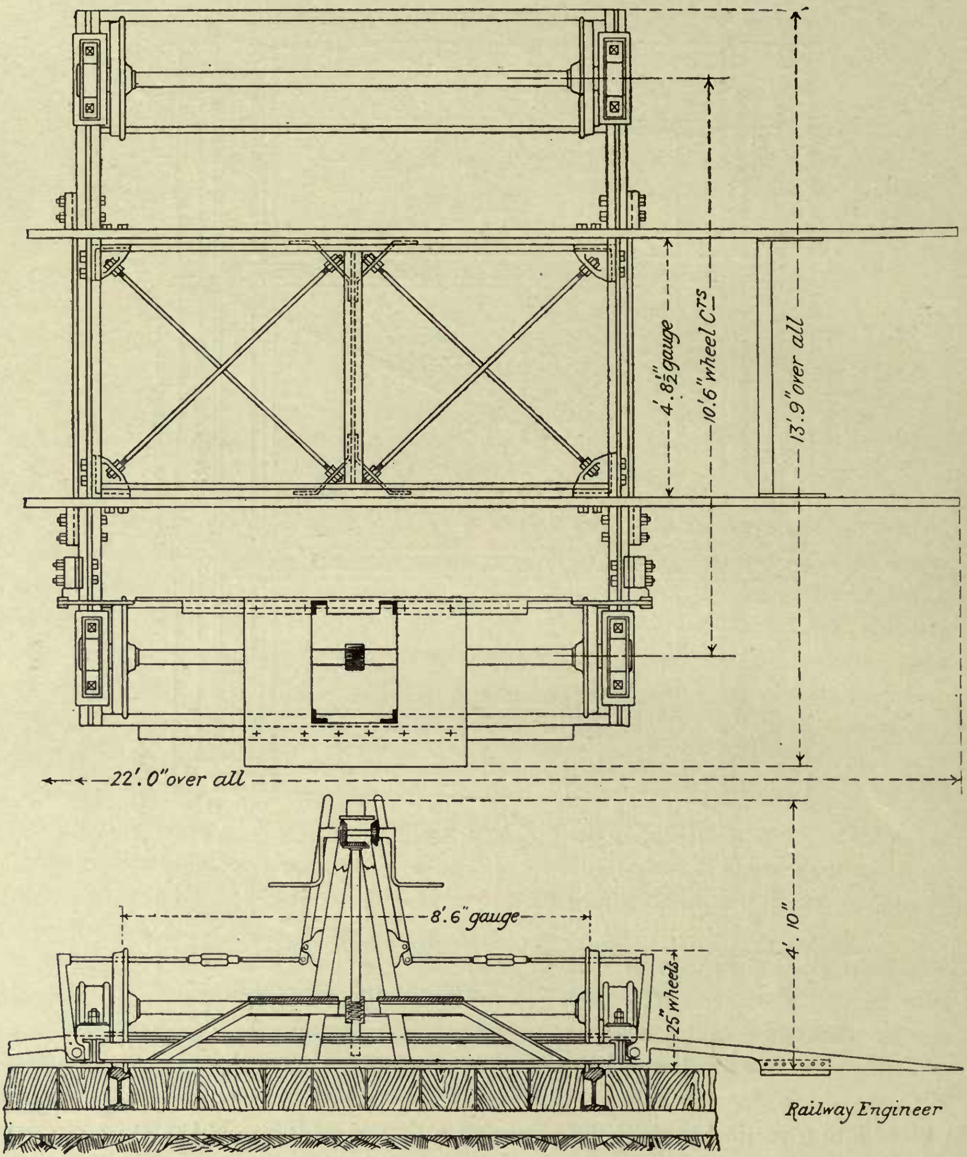


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Fig. 128. Wharton & Co.'s Traverser.

and, obviously, can be made at a much less expense than either of the others described.

Dick, Kerr & Co.'s Traverser.—

Fig. 130 shows a traverser as made by Dick, Kerr & Co. It is similar in construction in many ways to the one last mentioned; it does not involve any interference with the general surface of the car shed, and differs from those previously described in being longer to accommodate bogie cars used on many tramway systems. It seems unnecessary to enter into a detailed description, as all essential details are shown upon the drawing. One little difference in detail may be pointed

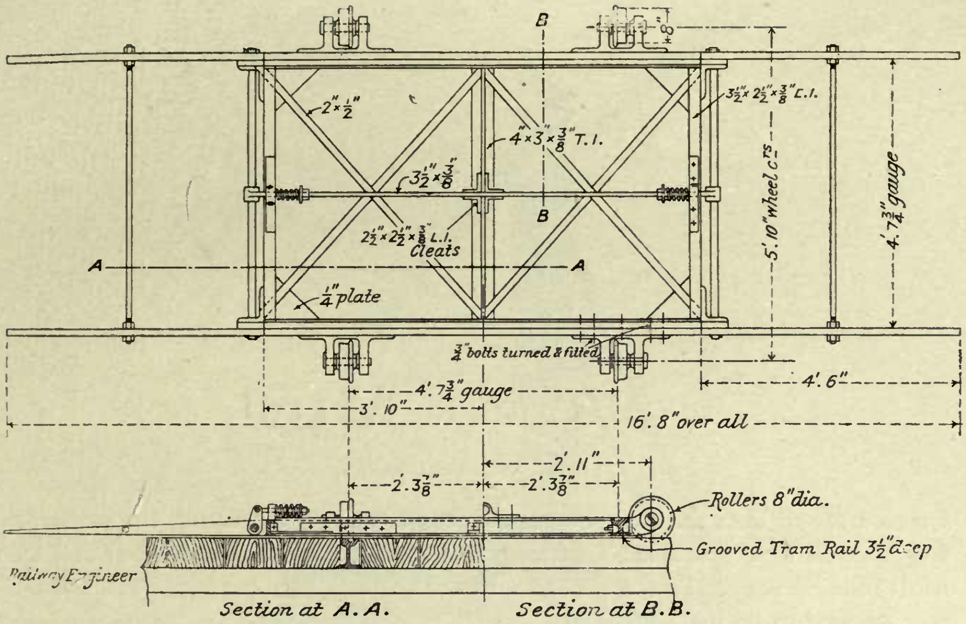


Fig. 129. Traverser used in the Glasgow Corporation Tramway Sheds.

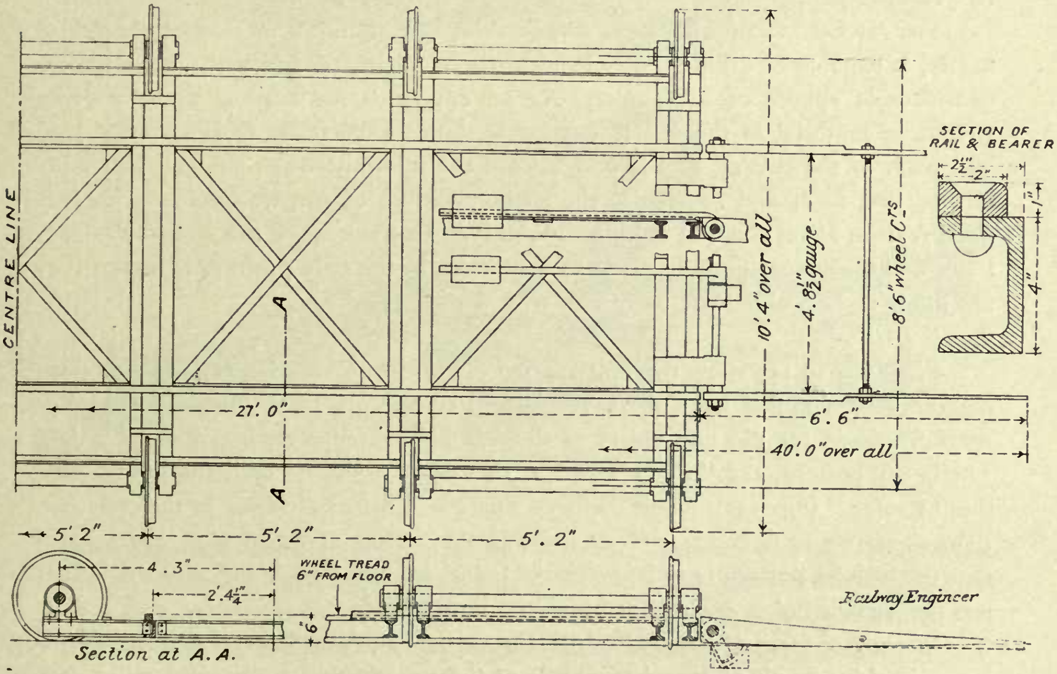


Fig. 130. Messrs. Dick, Kerr & Co.'s Traverser.

out, the inclined approach at the end is balanced by a loaded lever, and when it is dropped down on to the tracks, a latch in the centre of the axle carrying it falls into a socket in the floor of the shed, and thereby fixes the traverser in its proper position with reference to tramway tracks.

CHAPTER XIII.

TOOLS AND APPLIANCES.

Up to a recent date the tools and appliances used in constructing the permanent way were of a very simple character. The requirements of mechanical and electrical traction now call for more careful workmanship in platelaying, and the tools now deemed to be quite necessary show a great advance on the practice of even 10 years ago.

The ratchet brace, with a flat forged drill, is a standard tool which, in skilled hands, is capable of drilling holes in all sorts of positions, and will always have a considerable sphere of usefulness. As an appliance for cutting away a given weight of material in the shortest possible time its efficiency is abnormally low. The form of the cutting tool is bad, so are the intermittent action and still more intermittent feed, and so also is the sitting posture of the workman. The only good feature about the tool is its adaptability. In track work this is of no advantage, and machines specially made to drill holes in the only position in which they are likely to be wanted are more effective in their results.

Track Drills.—

Figs. 131 to 135 show the construction of two forms of a machine of American manufacture supplied by Robert W. Blackwell & Co., Ltd. Either machine is specially made for the one object of drilling holes in the vertical web of a rail. The heavy pattern, the "Buda" (fig. 133), weighs about 90 lbs., the lighter one, the "Paulus" (fig. 132), about 60 lbs. There is a little difference in the construction, as shown in figs. 104 and 105, and in the matter of working it may be said that the heavier pattern is to be preferred for ⅞ in. and 1 in. holes, and the lighter one for smaller holes, such as are required in bonding.

In another form of the Buda drill, the vertical shaft with bevel driving wheels is replaced by a pair of sprocket wheels at the top, driving a pair of smaller ones on the drill spindle below by means of chains. The combination is practically two ordinary bicycle gears. One of the chains gears to the drill spindle, the other drives the feed nut; in the same direction, but at a rather faster rate, so that a continuous feed is given to the drill. This machine is suitable for small holes only. The greater strength and stiffness of either of the machines described above

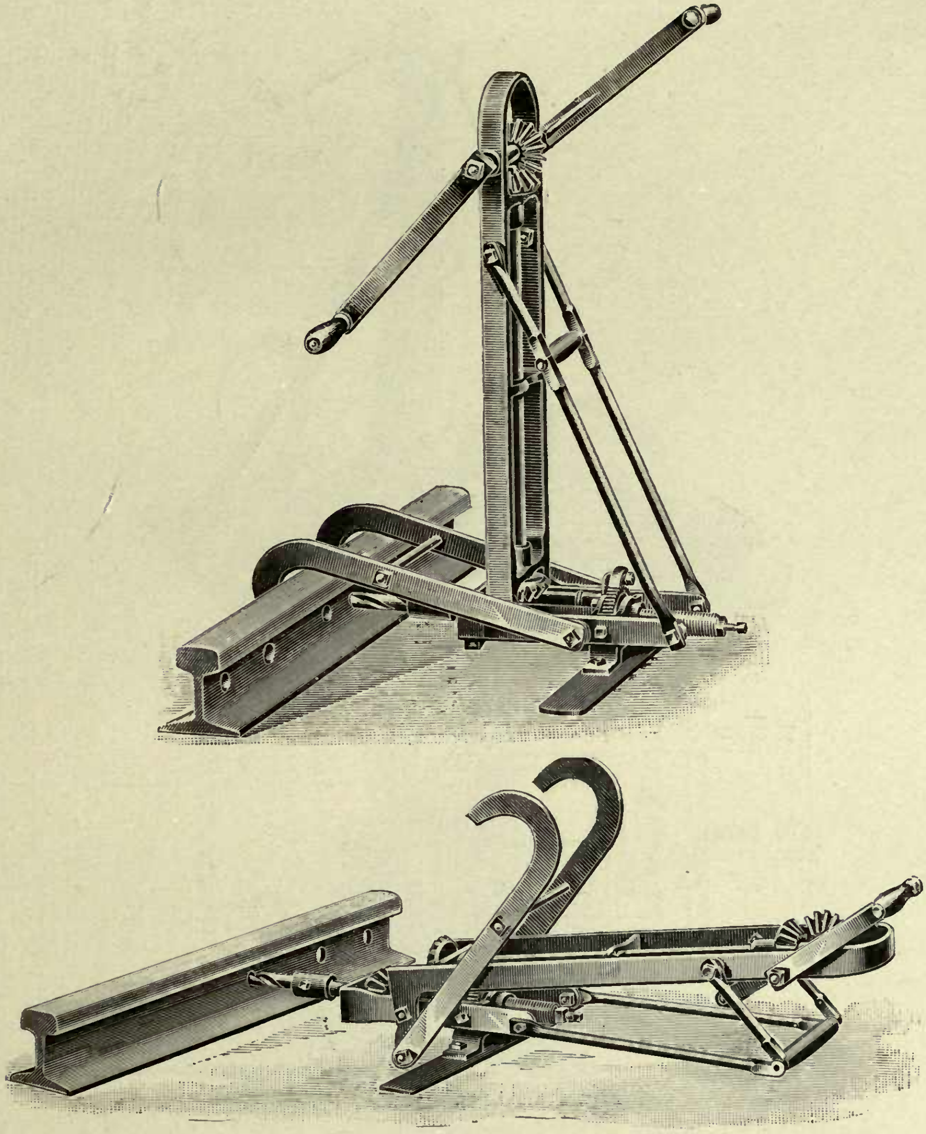


Fig. 131 and 132. "Paulus" Drill.

make it more suitable for general work. As compared with the old-fashioned ratchet brace and drill, the man stands up to the work, and the metal is cut away by a twist drill instead of being scraped away. The feed is quite automatic, and is such that, at a normal rate of working, the ½ in. web of a rail is pierced in about 2 minutes. It is not easy to give the corresponding particulars in the case of a ratchet and brace.

Rail Saws.—

The ordinary way of cutting a rail is to nick it all round with a cold sate, and then break it with a jim crow. This is noisy and objectionable, especially in

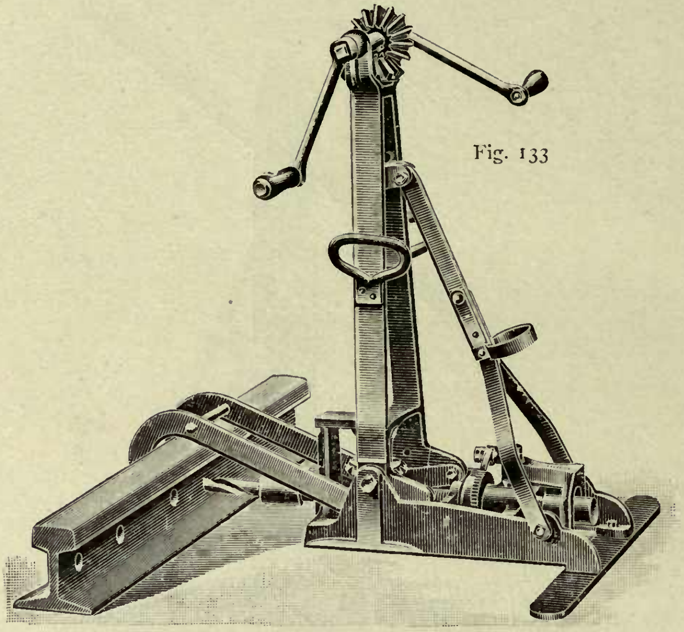
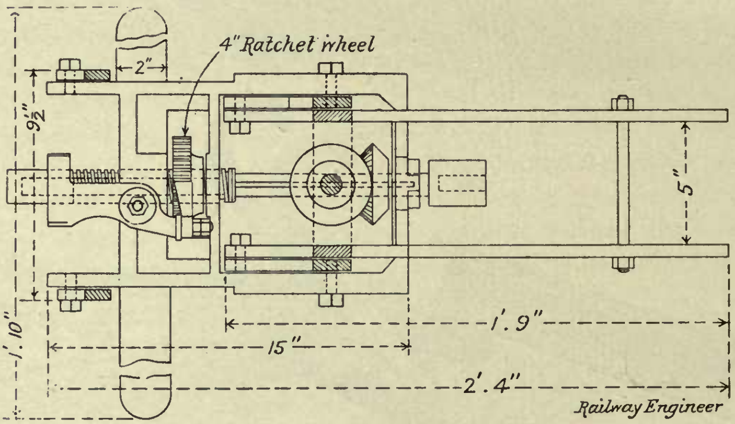


Fig. 133



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Figs. 133 and 134. "Buda Drill."

town, and it is impossible thus to so cut a rail as to make a close butted joint. This can only be done when the rail is sawn through.

Fig. 136 illustrates the "Whardown" saw, as supplied by Laing, Wharton & Cunnington, specially made for this purpose. The saw and its gearing are mounted on a cast iron pedestal, separate from the base frame. This straddles the rail to be cut, the jaws in front grasping it firmly, and the whole machine then being steadied by legs at the outer corners, adjustable to suit the irregularities of the ground. The saw is driven by a double train of cog wheels, the saw itself being the last wheel of the train; the back of each saw tooth coming into gear with the driving pinion in the same way as the tooth of an ordinary spur wheel. The saw is fed downwards by a slow automatic motion of the usual character.

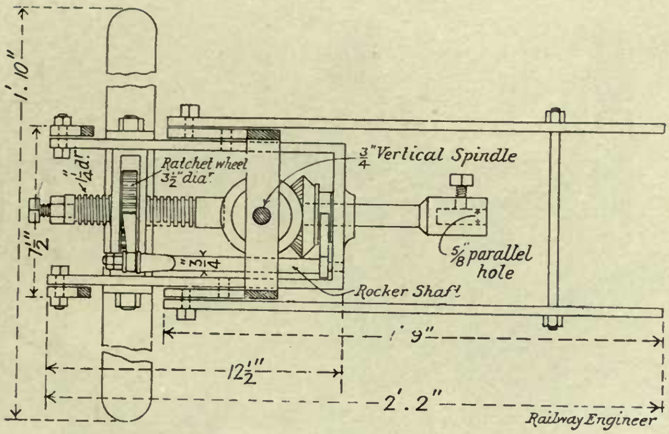


Fig. 135. "Paulus" Drill.

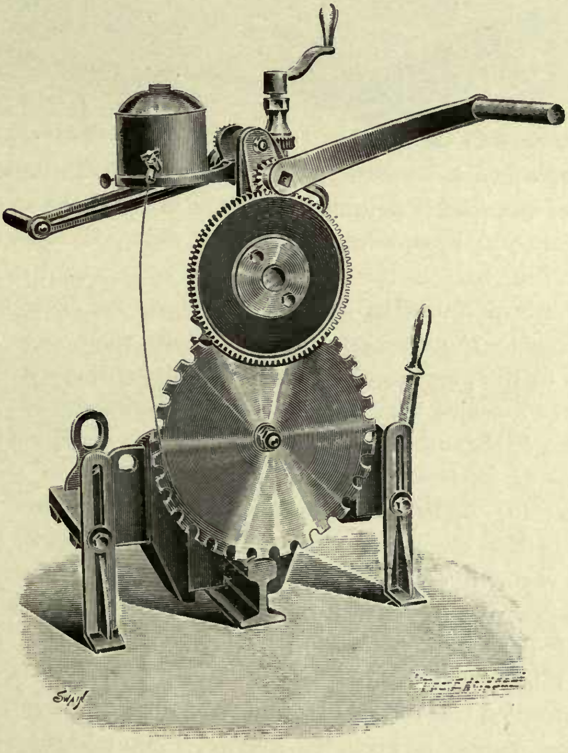


Fig. 136. Whardown Rail Saw.

Some of these machines are made to give a square cut only; in others the saw pedestal and gearing may be adjusted round a vertical axis so as to cut a rail at any angle up to 45° with the line of square.

It is essential to the smooth working of this saw that the sharpening be properly attended to, and the cutting edges of the teeth kept accurately spaced from the centre: this is not a suitable job for a three-cornered file, as the blade is ¼ in. thick. The sharpening is done by an emery wheel on a special frame

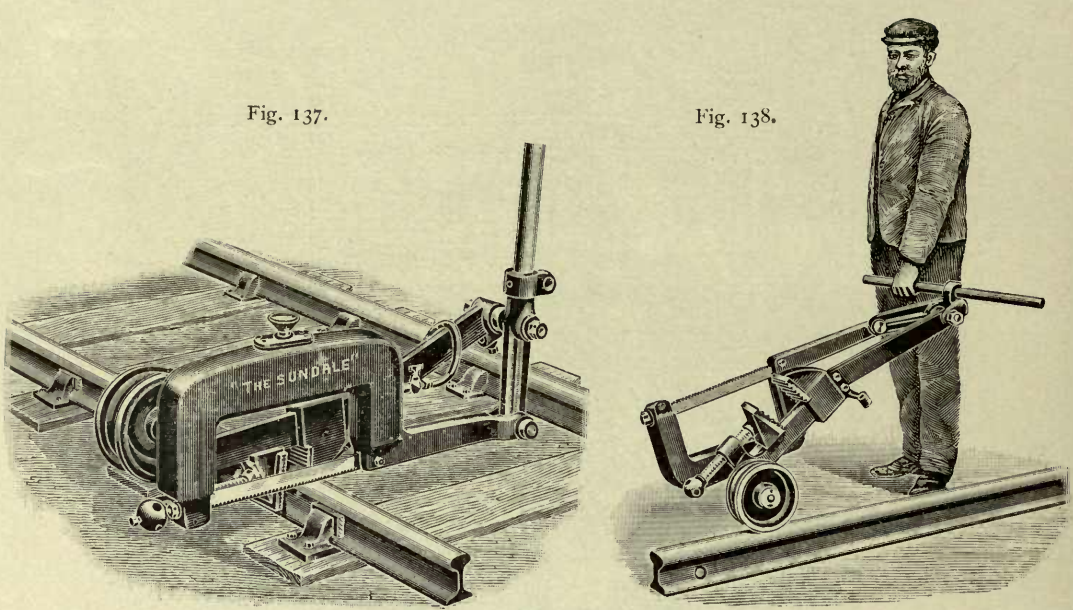


Fig. 137.

Fig. 138.

Figs. 137 and 138. "Sundale" Portable Rail Saw.

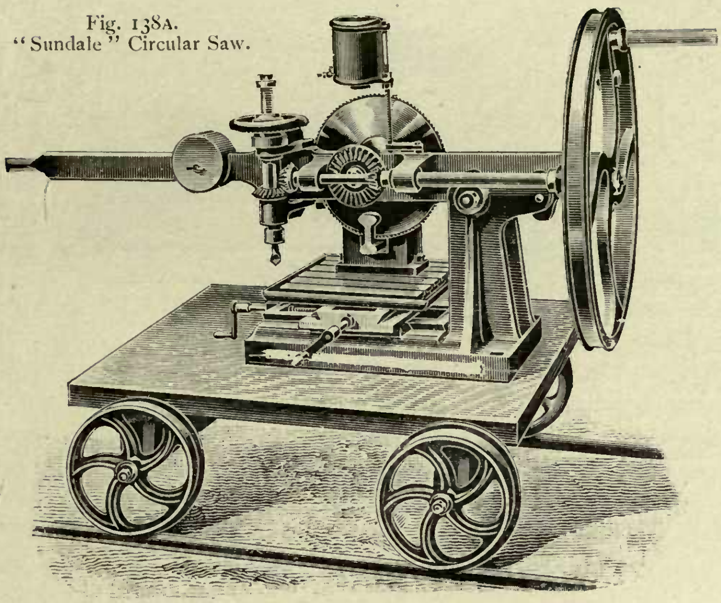
carrying the saw, which is so mounted that each tooth can be brought up to and across the face of the wheel, an adjustable stop limiting the motion of the frame towards the wheel so as to ensure the saw teeth being all left of the same length and angle of rake; the back of the tooth, which acts as a cog, is not touched.

These saws are of American origin. The parts are interchangeable and are kept in stock to replace the breakages which are sure to occur in work. This is of great advantage to the purchaser: it enables a damaged part to be replaced at a small cost, and the machine kept in use instead of being thrown on the scrap-heap at the first breakage, because of the expense of having some trifling piece specially made and fitted. It is, however, unfortunate that some of these parts are not stronger. To cut the modern high-carbon considerable power is necessary, and when the saw is cutting through the head of rail 3½ ins. thick, or the foot, nearly 7 ins. thick, it is certainly overloaded, and some of the parts are soon worn out.

The "Sundale" saw, shown in fig. 137, as supplied by Selig, Sonnenthal & Co., is a tool of quite a different character. Practically it is the ordinary hack saw adapted to this special work. It is fastened to the rail by means of the two jaws, and then steadied transversely by two adjustable legs bearing on the ground. The reciprocating motion is given by means of an upright lever, the pressure applied to the saw being merely the weight of the massive cast iron frame carrying it. There is, therefore, no mechanical feed mechanism necessary. An adjustable stay for stiffening the saw against this pressure is fixed to the saw blade as near the centre thereof as the work in hand will admit. By turning the saw over the machine can be conveniently moved about like a wheelbarrow, by running on the wheel shown in the figure (see fig. 138).

A "Sundale" saw of a different type is illustrated by fig. 138A. For tramway purposes it is mounted on a truck with plain flangeless wheels. It will cut rails

Fig. 138A.
"Sundale" Circular Saw.



at any angle and the slide-rest arrangement of the table makes exact adjustment an easy matter. The small saw-teeth are an advantage when cutting through the thin web of the rail, as there is but little risk of them getting broken. The tool can also be fitted with a removable vertical drilling attachment as shown in the illustration.

Rail Benders or "Jim Crows."

Fig. 139 shows the construction of a heavy jim crow of the ordinary pattern. In using a crow of this type the rail must be turned bottom upwards, so that the pressure may be applied to its foot. From a mechanical point of view the piece

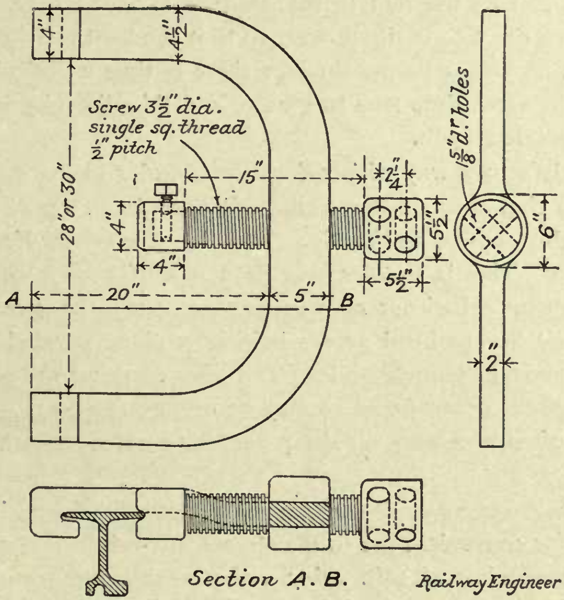


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Fig. 139. Rail Bender or "Jim Crow."

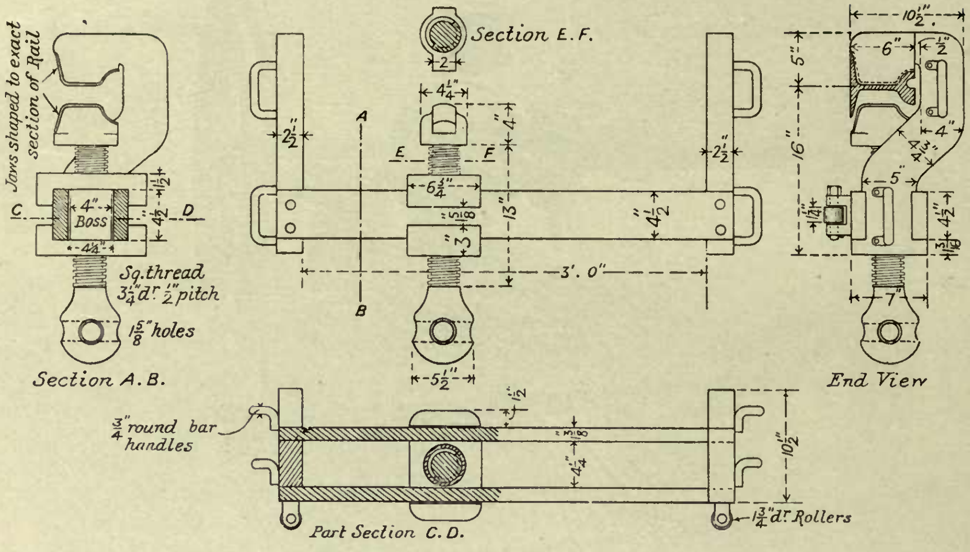

Fig. 140. Kenway's "Jim Crow."

of rail between the two outer jaws is in the position of a girder supported at each end with a concentrated load in the middle. This load is the pressure of the main screw, and it is increased until the deflection of the girder results in the degree of permanent set necessary to give the desired curvature. The foot, head, and web of the rail all have to be bent to this curvature, and, roughly speaking, it will take six times the pressure to bend the foot as it does to bend the head, even though the head may be the heaviest; the pressure necessary to bend the web is quite negligible in comparison. In using a crow in the manner described, the web has to transmit this bending strain from the foot to the head; this can only be done imperfectly, and in consequence the web is tilted over, so that the bent rail is distorted and the web and foot are no longer perpendicular : there is thus a difficulty in getting the top flat, and at the same time true to gauge, and this difficulty increases with the length of rail operated upon.

The only satisfactory way of bending an irregular shape such as a rail is to form the jaws so that they fit the section all over from top to bottom, and the pressure is thereby applied uniformly. This is effected in Kenway's crow, as shown in fig. 140. This is the drawing of a powerful crow capable of bending expeditiously the heaviest girder rails in use, and no turning over of the rails is required. The rail has to bend as a whole in a plane parallel to the foot, and tilting over or distortion is impossible. The boss carrying the screw is moveable laterally, so that the bending pressure may be brought to bear close up to the end of a rail : this is often necessary on sharp curves to get a smooth line through the joints.

The hydraulic crow, as made by Messrs. Tangye, is shown in fig. 141. It is rather too heavy for convenient use in the streets, its weight being about 5¾ cwts.; the jaws have an opening of 2 ft. 4 ins., the press being tested up to 60 tons. A machine like this is best adapted for bending rails in the yard, and, speaking

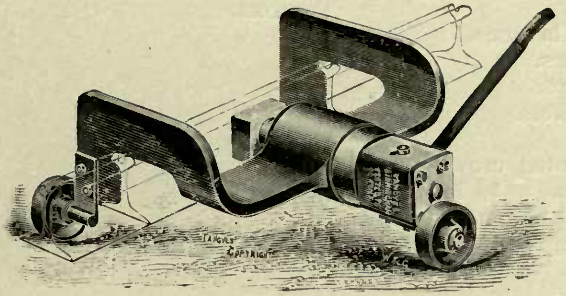

Fig. 141. Tangye's Hydraulic Rail Bender.

generally, this is perhaps the proper place to do it, especially if the bent rails are required in combination with points and crossings. All such bending is best done on an accurately levelled wooden floor, the wheels carrying the crow being so adjusted that the jaws engage with the rail as soon as the pressure is applied, without the necessity of lifting the rail into them. The bending can then be carried out exactly to predetermined curves, either to a template, or to lines and dimensions marked upon the floor. Accuracy and stability in complicated pieces of special work are not to be attained in any other way.

Navvies' Track Tools.—

The tools above mentioned are only a few of the most elaborate of the appliances necessary on track work; those of a more simple character need not be particularly described, although they may perhaps be equally necessary for the work. It may, however, be of interest to enumerate them, and the following may be taken as a list of what should be provided for a complete construction "gang," *i.e.*, the squad of men working on a section which is opened out at one time. This would be about a quarter of a mile in length, and would include work in all stages of progress, from the breaking up of the macadam roadway in front to the finished paved tramway behind. The carting is a separate item, and is often arranged for with local hauliers.

EXCAVATORS.

4 doz. 2 ft. 6 ins. × 1¾ ins. octagon steel wedges.
4 doz. sledge hammers.
4 doz. round shovels.
4 doz. square shovels.
20 ash levers for breaking up macadam.
8 doz. picks.
12 doz. pick shafts.
30 wheelbarrows.
2 1 yard gauge boxes.
2 ½ yard gauge boxes.
4 large concreting boards.
3 water stand-pipes.
4 tarpaulin cement covers.
20 water-cans.
30 buckets.
3 straight edges, 8 ft. to 12 ft. long.

PAVIORS.

1 doz. cane brushes.
2 pitch boilers.
4 pitch scoops.
12 pitch buckets.
6 rammers.
6 chisel pointed crow-bars (small).
1 doz. 18 ins. × 5/8 in. round pins.
1½ doz. reel hammers.
1 doz. cutting hammers.
3 tool boxes.

PLATELAYERS.

1 doz. fish-bolt spanners.
1 doz. tie-bar spanners.
2 track gauges.
2 doz. beaters, for packing rails.
2 jim crows, 1 large, 1 small.
2 doz. cold sates.
2 drilling machines and drills.
2 ratchet braces, cramps and drills.
4 tool boxes.

GENERAL.

1 pay office.
4 watch boxes.
4 doz. red lamps.
4 doz. fencing standards.
500 yds. fencing rope or chain.
3 notice boards.
12 fire buckets.
2 sets of boning rods.
½ doz. ranging rods.
120 yards strong setting-out line.
2 doz. iron pins, 18 ins. × ¾ in. round.
3 doz. 2 ins. × 2 ins. × 18 ins. wood pegs.
1 measuring chain.
2 measuring tapes.

Supply of pens, ink, paper, chalk, time-books, carters' check tickets and sundries.

CHAPTER XIV.

BONDING.

SOME of the electrical features of a modern tramway cannot be omitted from a book treating of its permanent way. The rails form an essential part of the electric circuit furnishing motive power to the cars, as well as forming a smooth rigid track for them to run upon. The continuity of this circuit must be maintained or the power will fail. If its conductivity is not maintained at a high value, power is wasted, certain Board of Trade bye-laws are infringed, and unknown damage may result to gas and water mains and other metallic conductors buried beneath the road surface.

The electric circuit supplying the power is made up of two parallel and indefinitely extended branches : the one connected with the positive pole of the generating dynamo is called the "line" by the Board of Trade; it is the overhead wire of an ordinary tramway. The other branch, connected with the negative pole, is called the "return," and is wholly or in part made up of the rails themselves. Both line and return may be supplemented by "feeders," but this does not affect the argument. The "line" is carefully insulated everywhere; the return may also be insulated as on a conduit tramway ; if it be not insulated the Board of Trade require it to be of "low resistance." No attempt is made to insulate the rails of an ordinary electric tramway.

The dynamo is not a generator of electricity; it generates an electric current, drawing it in at the negative brush on the armature, and forcing it out at a certain pressure through the positive brush. It thus acts as a sort of electric pump, and its function is to keep the line charged with electricity at the predetermined pressure. There is no current in this wire so long as its insulation is maintained : no work is being done, and no load is thrown upon the engine except that due to mechanical resistances. When the line and return are electrically connected through the motors on a car a current flows, its quantity being regulated by the driver according to the momentary requirements of the car. The magnetic resistance this current encounters in the motor is a measure of the energy with which it pushes the driving mechanism. In a sense, the current is a new one; its existence is only possible because of the path opened up for it through the car motor; it is complete and continuous through the line, the motor, the return, and the generator and its maintenance constitutes a fresh load upon the engine.

The same remarks would apply to every car upon the track; each fresh motor brought into action opens a new sluice for the passage of current from the line to the return. The total volume of current passing through two corresponding points on the line and return will be the sum total of all the currents due to the motors in actual work between that place and the extreme end of the track, apart, of course, from such modifications as may be introduced by line and return feeders. It thus follows that the nearer the generator the greater will be the volume of current to be accommodated, and the greater will be the necessity for looking after and augmenting the conductivity of the circuit, both line and return.

It is more usual to discuss the "resistance" of a conductor than its reciprocal, the "conductivity." The resistance of any homogeneous conductor varies directly as its length, and inversely as its area of cross section; both must be taken into account, besides the nature of the conducting body itself. Apart from its dimensions the resistance of a body or material depends upon its "specific resistance," which is generally stated as the actual resistance measured in ohms. of a centimetre cube of the material in question between two parallel faces of the cube. Thus, for copper and iron, Larden gives the following values :—

Copper = ·000001616 ohms. per cubic centimetre.
Iron = ·000009827 ,, ,, ,, ,,

For equal areas of cross section iron has therefore a resistance about six times as great as that of copper. These values are for pure metals. The conducting power of copper used for electrical purposes is generally good, and may approach very nearly 100 per cent. of the value given above. That of steel rails, however, is very different from the value given for iron; the addition of carbon, and still more so of manganese, causes an increase in the resistance altogether out of proportion to the quantity of the foreign elements introduced. The resistance of steel from which rails are made may be taken as from ten to twelve times that of copper, the lower value corresponding to the softer steels, such as are now generally judged not suitable for tramway works. By reducing the quantity of carbon and manganese sufficiently, a steel may be made having a resistance only about eight times that of copper; it is too soft for the track, but is eminently suitable for the working conductors on conduit or "third rail" constructions.

It may be taken that eleven is a fair average value of the resistance of steel rails not known to be specially hard. The cross section of the two rails of a track laid with 90 lb. rails would then be (very nearly) 18 sq. ins., and this divided by 11 = 1·63 sq. ins. as the cross section of a copper bar of equal conductivity; this would of course be doubled for a double track. The rails, however, are not continuous, and the resistance of the track will be the resistance of the rails plus that of the joints, and it is of some importance that this last element be reduced as much as possible.

There are good reasons why no arrangement of fish-plates and bolts can make a satisfactory electrical joint, although such a joint may have a substantial value in assisting the passage of the current. Iron oxide is an insulator; *i.e.*, its specific resistance is abnormally high; but the film between two tightly bolted surfaces may be very thin, and the area relatively very great, so that as a result the resistance between them may be quite low, and the fish-plates will then afford passage for a substantial proportion of current from one rail to the other. When a joint becomes loose the movement under the traffic generally causes the formation of one or two bright spots where the rails and plates rub against each other, and these would compensate for the loss in other parts of the joint where the surfaces are no longer held in close contact. Mr. Parshall made some experiments a few years ago on some 83 lb. rails, and found that with fish-plates uncleaned and not fully tight the average additional resistance of the joint was equal to a length of about 34 ins. of solid rail, and was only about one-third the resistance of a single OOOO bond 30 inches long. In another case, on 65 lb. rail track, one OOOO bond and fish-plates not tight, the additional resistance due to joint was equal to 57 ins. of rail; when the fish-plates were removed it was equal to 74 ins.; and with the fish-plates replaced and well tightened up the resistance fell an equivalent length of 39 ins. of solid rail.

These experiments tend to show that the resistance of an ordinary joint may not be too great to prevent it being of material service in increasing the conductivity of the track beyond what would be given by any bonds alone. It is, however, too uncertain to be depended upon : fish-plates buried under the road service cannot be kept tight; any looseness permits the entrance of water, and will probably set up electrolysis, causing an excessive oxidation of the rail in one place and of the plates in another. It is, therefore, always necessary to "bond" the ends of the abutting rails together in some way, so as to preserve the electric continuity of the track in spite of the mechanical imperfections of the joints. Some of the many ways that have been proposed for effecting this will be dealt with later.

If the joints are most effectively bonded and the electric continuity of the track is thereby rendered perfect, it by no means follows that the return current will be confined to the rails : this could only be assured by perfect insulation or perfect conductivity. Both are out of the question, and consequently every available path for the return current will be traversed by some portion of it : it will be divided amongst them according to their respective conductivities and the pressure or voltage available. The paving, &c., surrounding the rails are very poor conductors when compared with any metallic body, but they possess a substantial conducting power in consequence of their enormous bulk. Omitting the top and groove, the contour of an ordinary 7 ins. rail is about 30 ins., and the 4 rails of a double track therefore expose an area of 10 square feet of surface per foot run in contact with surrounding bodies, or more than 50,000 square feet per mile. With such a vast surface of contact it is evident that an exceeding minute leakage per square foot would result in a very large escape of current into the earth. No system of bonding can prevent this leakage; all that can be done is to make it so perfect that the conductivity of the track is utilised to the utmost.

The danger to other buried conductors from these leakages arises only from electroylsis at the places where the wandering currents leave the conductors to enter the moist earth again on their way to the negative side of the dynamo. No possible damage can be done by the passage of a current into and along a pipe, nor by its leaving the pipe again, so long as its escape is effected by *conduction.* But electricity passes through the general body of moist earth by *electrolysis*, and not by conduction; the electrolyte is the moisture in the soil; *i.e.*, water with variable amounts of different salts and other matters in solution, and of more or less potency in facilitating the process. The passage of the current must decompose the water, and oxygen will be given off at the metallic surface only where the current enters the liquid; it will attack the metal and produce the well known effects of electrolytic corrosion. We are not concerned with what goes on in its passage through the moist earth, but where the current leaves it and again enters a metallic conductor hydrogen will be given off. This can have no injurious effect upon the metal; it may even tend to preserve it by combining with oxygen, which would otherwise be available for corrosion.

The general tendency will obviously be for electricity to leave the rails and enter the pipes in remote districts and to leave them again in districts nearer to the generating dynamo. Many things may conspire to make these districts indefinite, and in particular the track of the pipes may be very different from that of the tramway, or from the most direct way to the dynamo; and again, the arrangement of these districts will very likely be different in summer, when the soil is dry, to what it will be when everything is wet and damp in winter. As the electricity in these stray currents gets into the earth from the rails, it follows that they also are subject to electrolytic corrosion; but the surface over which this leakage is spread is so great, and the average current density therefore so low, that the damage done will be quite inappreciable; the rails will be worn out on the top long before the corrosion on their sides has become sufficiently great to interfere with the stability of the track.

The means by which bonding is effected may be divided into three classes, viz. :—

A. Copper bars or cables, plugged or rivetted at each end to the rails.

B. Forming the connection by means of a plastic amalgam, and using the fish-plates as the connecting link.

C. Welding—either,

a. By actual welding together of abutting rails by the Goldschmidt process.

b. Welding small connecting lugs to the ends of the abutting rails by an electric current.

c. By casting a mass of molten metal round the joint.

The majority of bonds in use belong to the first named class; they can be applied without any special preparation, and with ordinary tools and appliances to any kind of track, and they do not require any variation in the details of ordinary construction. They are now made of "high conductivity" copper; of a solid bar or wire when the length is sufficient to span across the fish-plates; of a cable or laminated structure when it is less than 12 ins. The hole in the rail is drilled the same size as the terminal plug, and this is then swaged or expanded by some means so as to force that part of the copper in the hole into intimate contact with its steel walls. The permanence of the electric connection largely depends upon the perfection of this contact; the least vacant space will admit water, give rise to electrolysis, and rapidly cause the plug to become loosened, and its efficiency to be impaired.

The size of the terminal plugs is so proportioned as to make the area of contact in the hole eight or nine times the area of cross section of the bond itself. The standard proportions of the "Chicago" bond are as follows :—

Size of wire. American gauge.	Sectional area.	Diameter of terminal.	Surface of contact in rail. ⅜″ thick.	$\frac{7}{16}$″ thick.	½″ thick.
0000	·166	⅞ in.	·98	1·15	1·31
000	·132	¾ in.	·88	1·03	1·18
00	·104	⅝ in.	·735	·86	·98
0	·083	½ in.	·588	·69	·785

The corresponding particulars of the "Neptune" bonds are given as follows :

6/0	·169	⅞ in.	·98	1·15	1·31
4/0	·126	¾ in.	·88	1·03	1·18
00	·095	⅝ in.	·735	·86	·98
0	·082	½ in.	·588	·69	·785

These two tables illustrate the confusion caused by different systems of wire gauges. The "Chicago" sizes are according to the American, or "Brown and Sharpe's" numbers, whereas the "Neptune" bonds are classed according to the numbers of the English standard. These again are quite different from the old "Birmingham" gauge numbers. The best way of avoiding ambiguity in the matter is to give the diameter of the wire in fractions of an inch.

The advantages of a thoroughly bonded track were not fully realised in the early days of electric tramways, and it was frequently sought to supplement the manifest imperfections of the return circuit as a whole by bonding the rails at intervals to old car wheels, bundles of old rails, or other forms of "earth plates" buried beneath the surface. When it was admitted that there was a necessity for some metallic connection between the rails independent of the fish-plates, this connection was frequently supplied by means of a wire soldered to galvanized iron plugs driven tightly into holes in the rail web. In No. 441/82 Varley & Judd patented the device of galvanizing with zinc or tin the rails, fish-plates and bolts, so as to make a good electrical connection; and with the same object in view, in No. 1862/82 (Edison) claimed coating ends of rails and inside of fish-plates with nickel, or other metal not easily oxidised by exposure to the air. Neither of these inventions came to anything; the galvanized plug proved imperfect and sadly lacking in permanence, and iron as a bonding material was soon displaced by copper. The ingenuity of bond inventors has perhaps found its greatest scope in devising means for making a permanent connection between the bond wire or wires and the steel rail.

Channel Pin.—

One of the earliest fastenings used was the Channel Pin, fig. 143. The hole in the rail was drilled about ⅛ in. too large for the wire, and a wedge-shaped steel channel pin slipped over the wire and hammered into the hole, jamming the wire into close contact with the steel rail on one side, and itself forming a connection with the wire on the other side. The current carrying capacity was increased

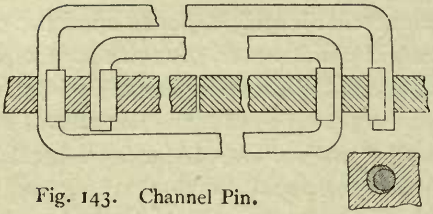

Fig. 143. Channel Pin.

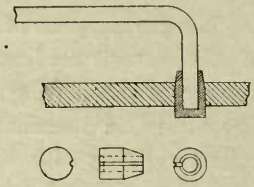

Fig. 144. Bonding Cap.

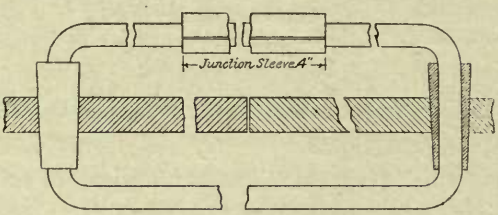

Fig. 145. West End Bond.

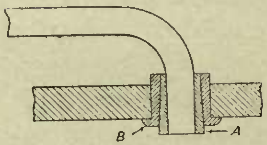

Fig. 146. American Bond.

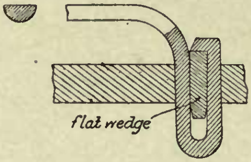

Fig. 147. Teck Bond.

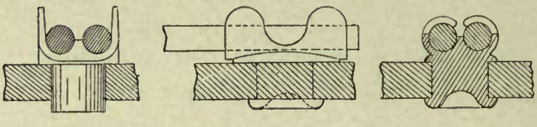

Fig. 148. Grauten Bond.

when required by drilling other holes in pairs, one on each side of the fish-plates, and looping a longer wire through them, wedging each hole as described.

Bonding Cap.—

The obvious imperfect contact afforded by the channel pin led to the introduction of the Bonding Cap, fig. 144, which is a soft steel cap or thimble, wedge shaped outside, with a longitudinal slit. When hammered into the rail it is compressed tightly upon the bonding wire, making contact with practically the full circumference of the hole.

West End Bond.—

This bond, fig. 145, is a distinct improvement upon these devices. Soft steel tapered sleeves about 1½ ins. long are tinned and soldered upon the bonding wire, and hammered tightly into the bonding holes. The free ends of the bonding wire are then brought together and united by soldering into a copper sleeve. The soft steel drifting plugs were used for effecting contact with the rail with the idea of avoiding possible troubles from electrolysis at this important junction.

American Bond.—

In this bond, fig. 146, the fastening at each end is composed of two copper tapered bushings, the inner one A having its taper on the outside. As this bushing is forced into place it grips the wire, and at the same time expands the outer bushing into close contact with the hole in the rail.

Teck Bond.—

This is a severely simple method of fastening. The wire, fig. 147, is of a half-round shape; the end is doubled up, bringing the two flats together, and pushed through the hole in the rail. A flat wedge is then driven in, forcing the wire into

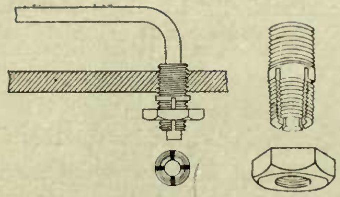

Fig. 149. Stern & Silverman Bond.

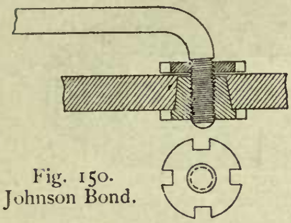

Fig. 150. Johnson Bond.

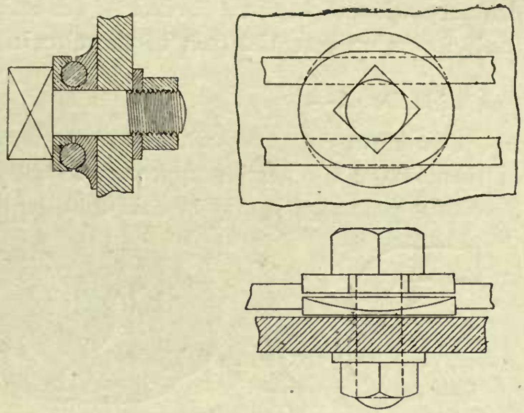

Fig. 151. Bryan Bond.

contact with the rail; the free end of the wire is then hammered over the top of the wedge to keep it in its place.

Grauten Bond.—

In the Grauten Bond, fig. 148, a separate tinned copper terminal is rivetted into the rail; the head of this terminal is formed into one or more semi-circular sockets of a diameter to suit the bonding wire, which is laid into one of them. The projecting ears of the socket are then hammered over and the wire finally soldered into place. The figure shows a terminal with two sockets, the second one being available to receive a second bond wire, a cross bond, or an "earth wire," *i.e.*, a supplemental conductor run along the track, and to which the rails were bonded at frequent intervals. This supplemental track return is now found to be quite unnecessary when the rails themselves are efficiently bonded.

Stern & Silverman Bond.—

In this bond, fig. 149, the fastening is composed of a chuck shaped brass or copper plug screwed externally and pierced with a hole slightly larger than the bond wire. One end of the plug is parallel and is screwed into the rail; the other end is split and sharply coned, so that as the nut is screwed up it closes the plug tightly upon the wire.

Johnson Bond.—

In the Johnson Bond, fig. 150, the wire itself is screwed and provided with two copper nuts, one of them being coned to fit a corresponding tapered hole in the rail. This nut is hammered into close contact with the rail, and the other nut is then run up, locking the bond in position. The bearing surfaces under the nuts were supposed to be faced, so that when the last nut was screwed up tightly an increased conducting power was expected from the large areas brought into contact. The probability is that a very small proportion of it only was effective.

Bryan Bond.—

In the Bryan Bond, fig. 151, this contact surface is much more likely to be effective. The massive copper washers gripping the bond wire are pulled into contact with the prepared surface of the rail by a substantial steel bolt, which in itself forms no essential part of the circuit.

Columbia Bond.—

The defects of some of these methods of fastening are fairly obvious; others of them make a tentative approach to the standard types of bond now in use. Speaking generally, it may be said that the tendency has been to exclude anything depending upon a screw, and to perfect the methods or efficiency of a rivetting attachment. One of these later forms is shown in fig. 152, and is known as the Columbia Bond. The conical terminal has a slightly projecting fillet formed round its base; it is fitted with a thimble, tapered internally to fit the cone, and externally forming an easy fit in the rail. When thus placed in position, the thimble is forced down and expanded over the cone, and finally clenched by a blunt centre punch.

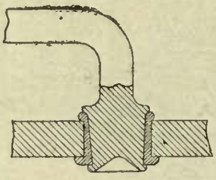

Fig. 152. Columbia Bond.

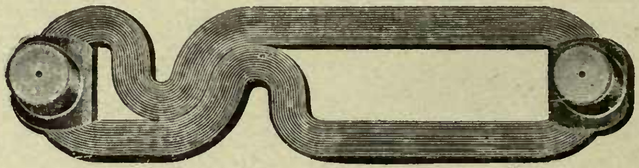

Fig. 153. Protected Bond.

Protected Bond.—

The terminal of this bond, which is made by the City Forest Electric Co., 3, Gore Street, Manchester, figs. 153 and 154, has a parallel plug, and the external thimble is omitted. The rivetting or expanding of the solid plug is effected by steady pressure. Fig. 155 shows a form of screw press, by the Forest City Electric Co., for accomplishing this. The outer screw is actuated by the hand wheel, and is used only to pull the bond terminal "home"; the end of the screw itself does not touch the plug as it is pushed through the hole. The inner screw is then applied and puts pressure upon the copper terminal only, which can only bulge outwards, forming the necessary contact between the copper and the inner surface of the hole in the rail.

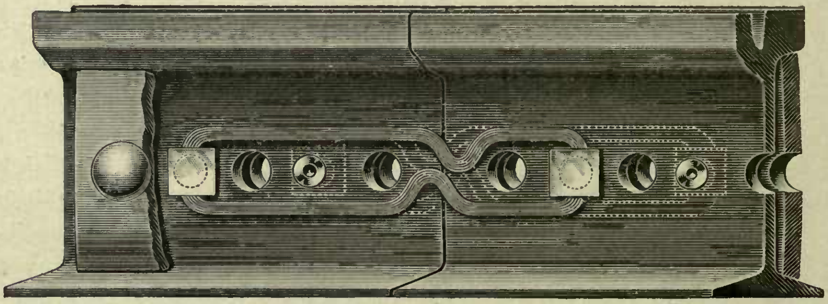

Fig. 154. Protected Bonds in Position.

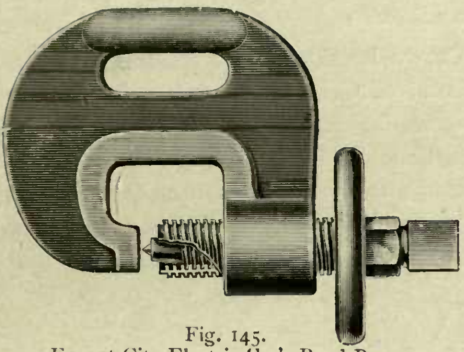

Fig. 145.
Forrest City Electric Co.'s Bond Press.

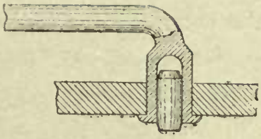

Fig. 156. Chicago Bond.

Chicago Bond.—

Fig. 156 shows the terminal of the Chicago Bond, which is expanded to fit the rail by an internal steel plug. The hole in the rail is drilled not more than $\frac{1}{64}$ in. larger than the terminal, whereas the drifting plug itself is $\frac{1}{16}$ in. larger than the hole into which it is driven. To properly fix a bond of this type, it should be "held up" with the shoulder on the terminal bearing tightly against the web of the rail, by a jointed lever made for the purpose, such as the one shown in fig. 157, and made by Askham Bros. & Wilson, Ltd., Sheffield. In the case of all bonds fixed by an internal drift pin, some such method of "holding-up" is advisable to increase the internal pressures in the copper itself, and to check the axial drag upon the metal as the pin is driven forwards. The metal will always flow along the line of least resistance, and this also fixes the intensity of the internal pressure which expands or bulges the terminal into proper contact with the rail in which it is fixed.

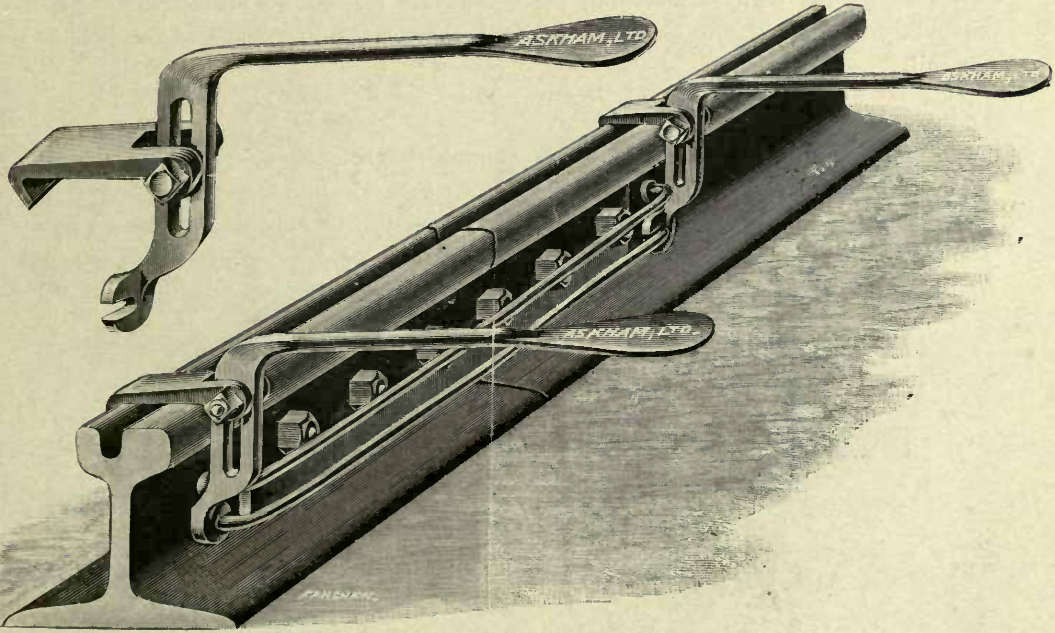

Fig. 157. Askham's "Holder-up" for Rail Bonds

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Chicago Crown Bond and the Neptune Bond.—

Fig. 158 illustrates the Chicago Crown Bond, and fig. 159 the Neptune Bond. The first is of American, and the second of German, manufacture. In both the leading feature is that the steel plug used for expanding the terminal is driven in from the same side of the rail as the bond itself. Fig. 158 shows the terminal fixed in place; in fig. 159 the section shows the terminal before the expanding plug is inserted : it is closed at the bottom, except for the small hole formed by the intersection of two saw cuts which limit and define the directions of spread of the metal as the pointed head of the plug is forced through it.

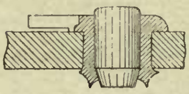


Fig. 158. Chicago Crown Bond.

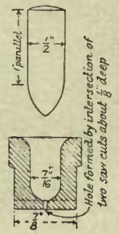


Fig. 159. Neptune Bond.

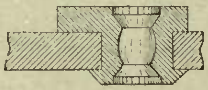


Fig. 160. General Electric Co.'s Bond.

General Electric Co.'s Bond.—

Fig. 160 shows a method of fastening recently introduced by the General Electric Co. The copper terminal is cast round a spool shaped steel pin or plug. The outer conical parts of this plug are hard, and project about ⅛ in.; the cylindrical piece connecting them is soft. When the terminal is in place a steady pressure is applied to the pin, forcing the heads together and bulging out into a barrel shape the softer connecting piece between them, and at the same time expanding the copper into close contact with the surrounding walls of the hole in the rail.

Victor Duplex Bond.—

Figs. 161 and 162 show the Victor Duplex Bond. The figures show a bond designed to be placed under the fish-plates, but this does not affect the method of fastening. Double bonding of the joints is effected with one pair of holes only. The terminals are slightly coned in opposite directions, and when placed in position from opposite sides of the rail fit into each other as shown, and are finally expanded

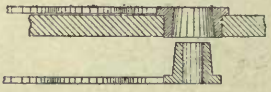


Fig. 161. Victor Duplex Bond.

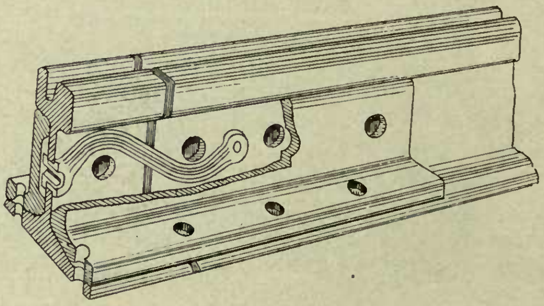


Fig. 162.

by driving in a steel pin or plug. Or otherwise, the inner terminal may be solid, and the expansion effected by means of a screw or hydraulic press.

Expanding Bond Terminals.—

There has been some diversity of opinion as to the proper way of expanding the copper terminal, and also as to the area of contact required between the copper and the steel. As to the first matter, it does not appear that hammering a drift-pin into a central hole somewhat too small for it is the best means to adopt. The hole made by a twist drill is never circular, and as the copper expands it comes into contact with the walls of the hole in three or four places only. A great increase in the effective pressure is then required to bend the copper between these bearing surfaces; the metal bends or flows in consequence of the pressure brought upon it, but the line of least resistance will very likely be sideways, in the direction of the drag put upon it by the drift-pin. When the terminal is "held up" by some such device as shown in fig. 157, this drag is checked, but when a solid plug is expanded by steady pressure it cannot exist. The soft metal is plastic under a sufficient pressure, and the only things likely to impair the perfection of contact are dirt and carelessness. Figs. 163 and 164 show a powerful hydraulic press adapted for giving a vertical grip, and used in fixing the bonds on the underground conduit conductors of the Bournemouth and the London County Council tramways.

Fig. 163 shows the compressor on a stand, as it is used on the pavement to fix bonds in one end of the conductor rail before the latter is placed in the conduit: Fig. 164 shows the compressor which is dropped through the manhole to connect up the various lengths which already have the bonds fixed in one end. It will be noticed that there is an iron frame, on which a pair of small wheels roll, from which

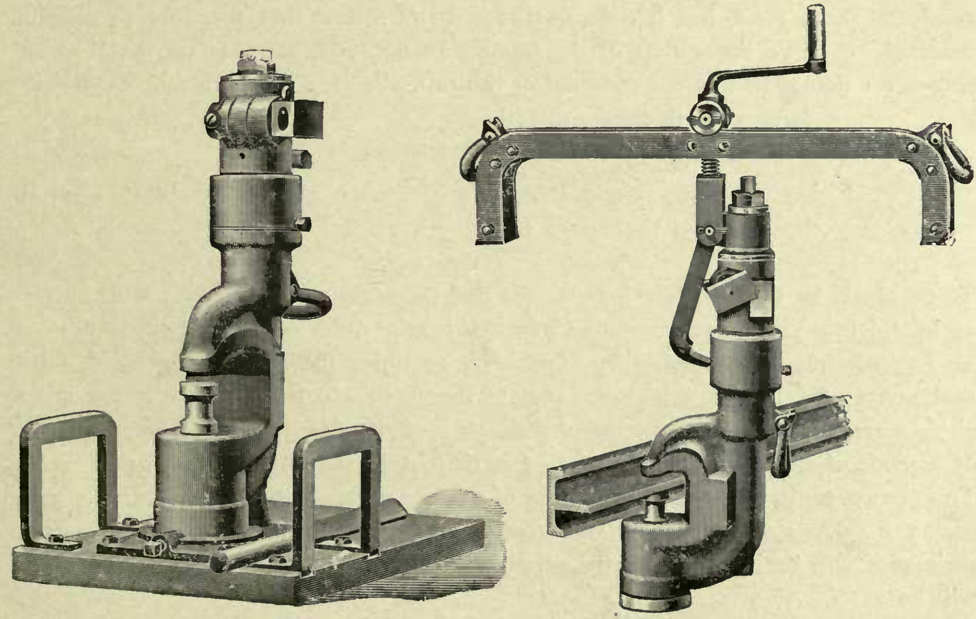


Fig. 163. Forrest City Electric Co.'s Bond Compressors. Fig. 164.

the machine is suspended, and also that there is a screw arrangement for adjusting the height of the machine in reference to the bonds.

Fig. 165 shows a very neat form by the Forest City Electric Co., adapted for a horizontal grip; the device for enabling the jaws to be opened wide enough to clear the head of a rail without interfering with the ram is decidedly ingenious.

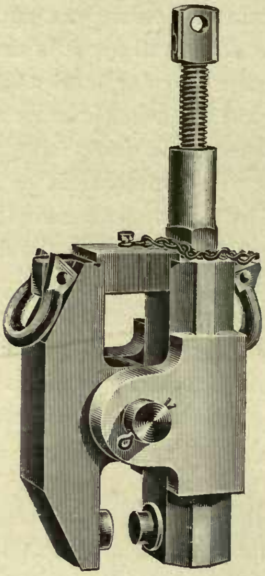
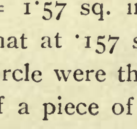


Fig. 165. Forrest City Electric Co.'s Bond Compressor.

Area of Contact.—

As to the area of contact, it is known that copper is 10 or 11 times a better conductor than steel, but it does not necessarily follow that the area of contact must be 10 or 11 times that of the bond. In fig. 166, suppose the inner circle shows the actual size of the terminal in the rail, the area of contact is = circumference × thickness of rail, say

$$= 2\ \pi\ r\ t.$$



Let the outer circle show size necessary to give a contact area 10 times that of the bond, say

$$= 2\ \pi\ r^1\ t.$$

To fix ideas, let the inner circle be ¾ in. and the outer one 1 in. dia., and the rail ½ in. thick. Then area of contact afforded by the outer circle = 3·14 × 1 × ·5 = 1·57 sq. in., which, being by hypothesis 10 times the area of the bond, fixes that at ·157 sq. in., or not quite equal to that of a 4/0 bond wire. If the inner circle were the same size, the radial resistance of the ring would therefore be that of a piece of the bond wire equal in length to this radial thickness, or ⅛ inch. This, however, is too small. The area of contact given by the inner circle = 3·14 × ·75 × ·5 = 1·18 sq. inches, and treating this as the base of the conductor, the resistance will be inversely as the areas, and the length of equivalent bond wire will be

$$\tfrac{1}{8}'' \times 1{\cdot}57 \div 1{\cdot}18 = {\cdot}23,$$

or very nearly $\frac{1}{4}$ inch. Obviously this is about as much too great as the other value is too small, so we may take it that the increased resistance due to one of the smaller terminals would be compensated for by shortening the bond wire $\frac{3}{16}$ in., or by $\frac{3}{8}$ in. to allow for both terminals.

If t be the thickness of the rail, ρ the specific resistance of the steel, r and r^1 the internal and external radii of the ring, it may be shown that its actual resistance in a radial direction is equal to

$$R = \frac{\rho}{2 \pi t} \int_{r}^{r^1} \frac{d r}{r} = 0{\cdot}366 \frac{\rho}{t} \log_{10} \frac{r^1}{r}$$

Of course, if ρ be the resistance of a cubic centimeter, t must be taken in centimeters also. Otherwise the given specific resistance given in terms of the centimeter cube may be adapted for use with measurements taken in English inches by *dividing* by 2·54. The larger cube must have the smaller resistance, inasmuch as it will be inversely as the area of cross section, *i.e.*, as the square of the side.

In any case the additional resistance due to the smaller terminal is a very small fraction of that due to the whole bond, and is of far less importance than the perfection of contact between the copper and steel.

CHAPTER XV.

CONDUIT PERMANENT WAY.

THE adoption of the cable system of haulage upon tramways introduced new problems in the construction of the permanent way. It is not likely that this system will receive extended application in the future; it is more likely that the existing cables will be replaced by electric conductors, and that the conductors will be in underground conduits, so that there will be little change in the appearance of the street surface. With such a conduit the general mechanical conditions are the same as with a cable line, with certain additional difficulties caused by the necessity of using a larger tube. In both cases the moving car has to maintain uninterrupted connection with the source of its energy in the underground tube by means of an apparatus extending downwards through an open continuous slot in the roadway surface. In the one case this apparatus has to be strong enough to transmit the mechanical pull necessary to maintain the motion of the car under all working conditions and against all usual obstructions; in the other case it need be strong enough only to maintain its own motion against the friction of the slot, &c. The electrical energy to be transmitted by it could be carried by a plate only a very small fraction of an inch in thickness. Nevertheless, this has little influence in reducing the width of the slot : the plates which conduct the electricity have to be insulated on both sides, and this insulation in turn has to be protected by other steel plates from damage by friction against the sides of the slot; this makes a total of 5 thicknesses of material passing along the slot, which therefore has to be practically of the same width as that required for the gripper of a cable car.

On a cable tramway there are good reasons for placing the tube and its open slot in the centre of the track : the gripper has to supply the whole mechanical force required for hauling the car. If this force were not applied in the centre extra wear and tear, and probably other mischief also, would arise from the side strains due to the unsymmetrical application of the pulling force. The central slot, however, means another set of metals in the street surface, and these are open to objection. They interfere with horses' foothold; they cut up the pavement into narrow strips, which are expensive to keep in repair : and the wheels of ordinary vehicles have to contend with six lines of obstruction due to the pavement being above or below the metals, instead of with four. There is no mechanical pull to be transmitted on an electrical tramway, and the tube *may* therefore be placed under one of the running rails, its slot serving as a groove to this rail. Other matters, however, have to be considered : the side slot has objectionable features of its own, and it is still a debatable matter as to which type of construction has the balance of advantage on its side.

The early cable conduits of San Francisco were of wood, and wood was also largely used in the construction of the first English electric conduit, viz., the one at Blackpool. It is a very convenient material whenever the work in hand contains much of an experimental nature. It is not, however, suitable for permanent work, where shape and dimensions have been decided upon, and with very few exceptions the tubes now in use have been constructed mainly of concrete. The shape is defined by a series of iron frames or yokes adapted to carry the slot beams, and spaced at distances generally varying from 3 ft. 6 ins. to 4 ft. 6 ins. apart. Moveable wooden templates or formers are fixed inside the frames, and the excavated space outside and at the bottom is filled in with concrete, completely embedding the yoke except the space inside and in contact with the wooden former, and thus forming the sides and bottom of the tube. The formers being removed, the exposed surface of the concrete may be plastered and touched up where necessary. The roof of the tube is practically formed by the horizontal parts of the slot beams, sometimes supplemented by an additional iron strip, as will be seen from the detailed description of individual examples of conduit work.

A tube of this kind, placed below the level of the surface upon which a street pavement rests, appears to have a good effect upon the stability of that pavement. This is certainly due to the fact that it is hardly possible for water to accumulate under the rails and paving setts; at any rate, to such an extent as to cause serious mischief. In an ordinary tramway there is nothing to prevent this water accumulating and filling every cavity below the top surface : it surges to and fro under the movements caused by passing traffic, and exercises a most destructive effect upon the track. More especially is this so when the road is paved with wood, always ready to float when free from marginal restraint. The tube forms a means of escape for this water, and it thereby materially reduces the expense which would otherwise be incurred in repairs and maintenance of the roadway surface.

Speaking still in general terms, it should be pointed out that a tube for cable traction may be constructed of much smaller dimensions than one required to receive the electric conductors required for tramways. In the first case, the tube must be wide enough to give free space for the gripper jaws, which do not project more than 2 ins. or 3 ins. on each side of the centre line, and it must be deep enough to prevent the cable touching the bottom in the sag between two pullies; the pullies themselves being low enough to allow the gripper to pass over them. By placing the pullies in specially formed pits between two yokes, a tube 12 ins. deep and 8 ins. wide is sufficient for cable traction. In an electric system the tube must be much larger than this. There are two conductors of opposite polarity, each two or three inches wide: to diminish the risk of short circuit it is not deemed advisable to make the distance between them less than 5 ins. or 6 ins., and for the like reason there should be 2 ins. or 3 ins. clear space between each conductor and the adjacent walls and roof of the tube. Thus an electric conduit must be somewhere about twice as wide as the tube sufficient for a cable, and though it need not be also twice as deep, the 12 ins. of a cable tube is by no means sufficient.

"Specials" in all tube works are troublesome and expensive. At the points two converging tubes run together into one. Where they first come into contact at the one end a cavity is formed double the width of the normal tube, tapering away to the normal at the other end. The roadway surface has to be supported over this cavity down to the very tip of the point, without interfering with the free working of the gripper on a cable line, or with the collecting devices on an electric line. A moveable tongue must be arranged in the street surface to open one or other branch of the slot to an advancing car. The facility with which these requirements can be carried out evidently largely depends upon the size of the tube. The moving rope introduces no great difficulty in the case of a cable tramway; it affects only one branch anyway. The positive and negative conductors of an electric conduit constitute a problem of quite a different class, and not of a mechanical nature. It is dealt with to a large extent by suppressing the conductors.

The tube must be effectively drained; either by frequent connections with the main sewer, or with a special shallower drain laid for the purpose. Without this effective drainage the cleanliness necessary for effective operation cannot be attained. On a cable tramway with the small tube above referred to (this description does not apply to all cable tramways) the supporting pullies, spaced about 40 ft. apart, have to be fixed in small pits extending about a foot below the bottom level of the main tube; every one of these pits will therefore require a separate outlet for drainage, and being so numerous, a special pipe drain will probably be the most economical way of dealing with them. In a larger tube not broken up by these pits, outlets must be arranged according to circumstances: they must be easily accessible for inspection and cleansing. The dirt that gets through the slot is generally light and easily washed away: heavy road detritus is probably due to the careless use of rotary sweeping machines, and much of it might easily be kept out by arranging a piece of light T iron in the slot, to be drawn along by the machine under the brush and in the track of the oblique stream of mud it pushes forward.

It is not proposed to deal with the pullies or other mechanism of a cable, or with the electrical fittings of a conduit tramway, except so far as they may affect the design of the permanent structure. The cable system of haulage has one effect that should be referred to. For a given service of cars it causes less wear and tear to the track than any other known system of traction. The rolling stock is constructed for carrying the passengers only, the additional weight due to the grippers and about 80 ft. of rope not being worth mention. In all other mechanical systems this wear and tear is much greater. With steam an engine is required weighing 1½ to 2 times the weight of the car and average load of passengers. With electric traction the additional load is much less than this, but still every car has to carry the extra load of two or three tons of motors and apparatus, besides being built of extra strength to withstand the stress of the machinery. With electric accumulators the additional load is about double this, but this case is hardly worth considering at the present day. It is also probable that the wear on the rails due to wheels under a rolling load is less than that due to wheels under the same load but at the same time transmitting the tangential stress necessary to keep the car in motion.

On a cable line the rope is not in the centre of the tube, but on the left hand, or "near" side, sufficiently far from the centre to be free from any mud or dirt that may drop through the slot. On curves it is kept within a couple of inches of this position by horizontal deflecting pullies. To keep the displacement from the normal position within the above mentioned limit, it is obvious that these pullies will have to be placed the more closely together the sharper the curvature. It is also obvious that these pullies must be on the concave side of the curve, or on the side towards the centre, and they must be sufficiently inwards from the slot to give a clear passage to the gripper. If now, looking along the cable in the direction of its travel, the road bends to the right, it is clear that the horizontal deflecting pullies referred to, being on the concave side of the curve, will be 5 ins. or 6 ins. to the right of the line of cable on the straight leading up to the curve, and would therefore tend to pull it off the bearing pullies. This is avoided by pushing the curve bodily over towards the left, so that the straight portion of the cable is a tangent to the first deflecting pulley. Where the bend in the road is to the left of the straight track, this kink in the line is not necessary.

The track is also diverted a little in this manner where it is necessary to ensure the gripper dropping the cable. As the car approaches this spot, the bottom jaw of the gripper being lowered, the deflection in the track carries the gripper sideways clear of the cable, which is thus entirely freed from the car. Conversely, a deflection in the track in the opposite direction ensures the gripper picking up a cable. A vertical depression in the track would have the same effect as lowering the gripper, but obviously this device can have but a very limited application in a public road: the same end is more conveniently attained by elevating pullies fixed above the normal level and behind a bend in the track which carries the gripper past them.

The slot beams have to be supported entirely by the yokes, and fastened in some way so as to offer substantial resistance to being forced inwards by an expansion of the pavement. On a granite paved road this expansion can only occur in the jointing material, and is best guarded against by keeping the heading joints between the setts as thin as possible. Where the road is paved with wood the blocks themselves will probably expand also. The future behaviour of wood paving in this respect is very uncertain: much depends evidently upon its condition when laid; its age; the changing seasons it has had to contend with, and the amount of watering, gritting, and other attentions it has received. In some seasons the most trouble from slot closing appears to be met with on the wood paved sections; in other seasons the granite is worst. The matter is a very obscure one, and no general statement of what can be expected to happen under given conditions can here be given.

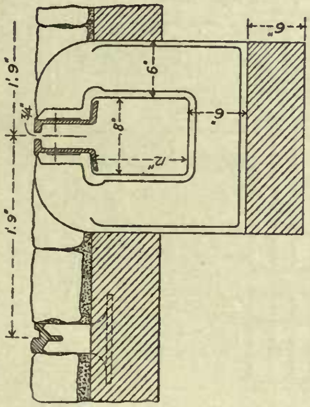
The normal width of a centre slot is about ¾ in., and the effects of wear and tear in increasing that width are mitigated to a great extent by the expansion above alluded to: the traffic in the street has little influence upon it. The conditions of a side slot, however, are altogether different. It must be at least an inch wide to accommodate the wheel flanges. The side lurches of the car, the centrifugal forces on curves, and the vibration due to the heavily loaded wheels, are always tending to pull the track out of shape and to loosen the slot beams. It is therefore evident that careful design and solid construction are very necessary to efficiency and economy of maintenance in the case of the side slot. The difficulties of carrying the heavily loaded wheels on the overhanging parts of the points, and the methods of dealing with them, must be reserved for treatment when dealing with particular examples of conduit construction.

The first cable tramway in England was constructed at Highgate, London, in 1884. This is the first example in England of a conduit tramway with a continuous slot in the street surface. The clause in the Provisional Order authorising the construction of this tramway reads as follows :—

> "The carriages used on the tramways may, subject to the provisions of this Order, be moved by mechanical power, that is to say, by wire ropes placed underground and worked by stationary engine power upon the system at present known as 'the Hallidie system of cable tramways' during a period of seven years after the opening of the same for public traffic, and with the consent of the B. of T. during such other periods of seven years as the said Board may from time to time specify in any Order to be signed by a secretary or an assistant secretary of the said Board."

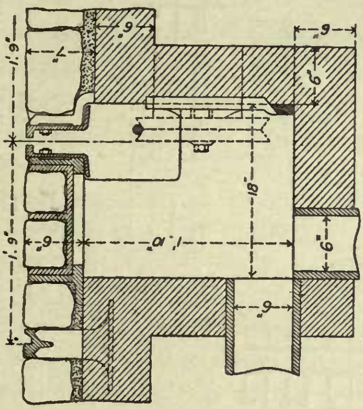
It is further provided that "The mechanical power used on the tramways "shall be fitted with such appliances for preventing the same from operating and "for bringing such mechanical power, and any carriage drawn or propelled by "such mechanical power, to a stand as the Board of Trade may from time to "time deem sufficient." The deposited plans make no reference to the novel character of the proposed works, and it will be seen that the clause in the Act left a good margin for the exercise of the B. of T.'s discretion in approving the plans. The line is about 57 chs. in length, of which 48 chs. is double line.

The construction of the tube and track is clearly indicated in figs. 167-169. The track is laid with Barker's rails to the gauge of 3 ft. 6 ins., the steel rails being about 45 lbs. per yd., carried upon and keyed to C. I. sleepers about 2 ft. long, laid about 3 ft. 6 ins. apart, centre to centre, so that there is a gap 18 ins. long between two sleepers, a type of structure which was improved upon in other tramways constructed about this time on the same system. The tube is of a rectangular shape, 12 ins. deep and 8 ins. wide; its outline is determined by a series of C. I. yokes weighing about 130 lbs. each, as shown in fig. 167, and spaced 3 ft. 6 ins. apart, centre to centre, the bottom of the tube being about 18 ins. below the street surface. The slot beams are 7 ins. deep and weigh about



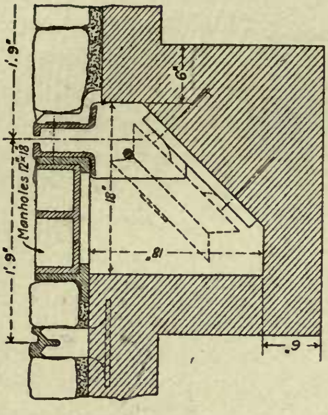
Section at Yoke

Fig. 167.



Section at Vertical Pulley Boxes

Fig. 168.



Pulley Box for Curved Track

Fig. 169.

Figs. 167, 168 and 169. Highgate Cable Tramways.

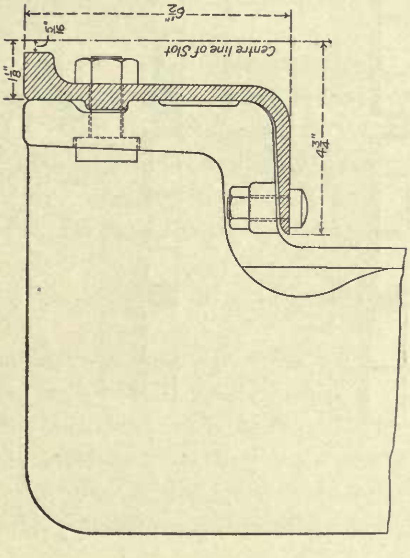


Fig. 170. Slot-way, Edinburgh Northern Cable.

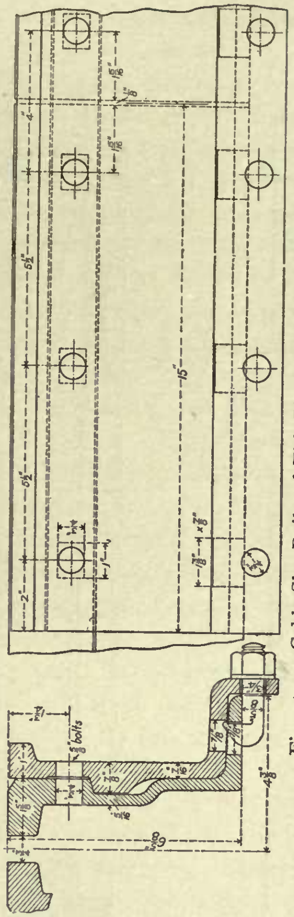


Fig. 171. Cable Slot Rail and Fish Plate, Edinburgh Tramways.

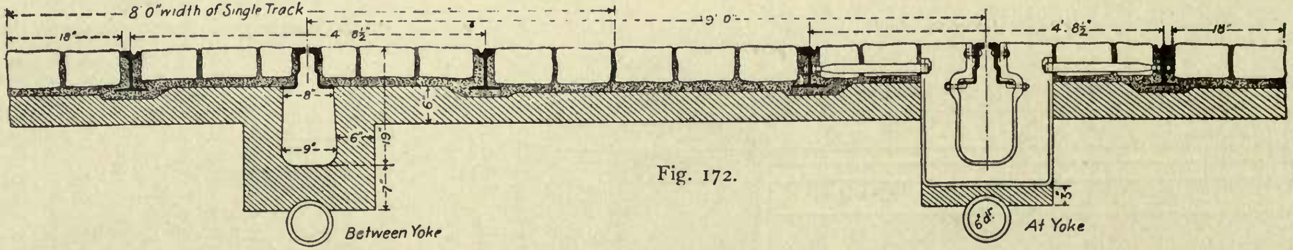


Fig. 172.

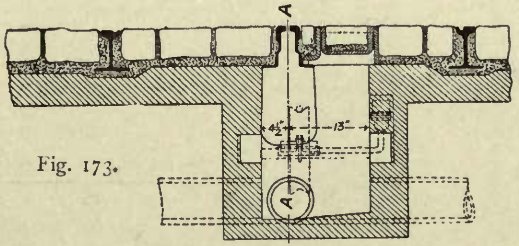


Fig. 173.

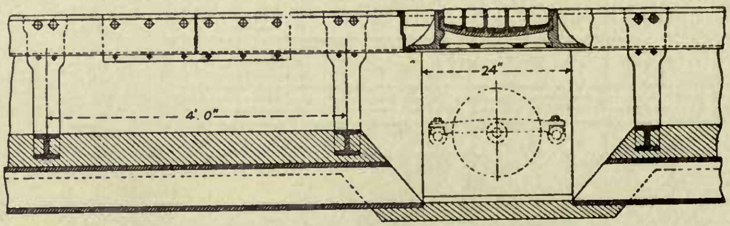


Fig. 173. Section A.A showing Slot Rail Joint & Pit for Vertical Pulley

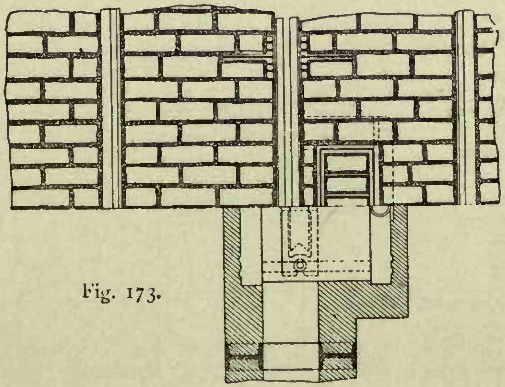


Fig. 173.

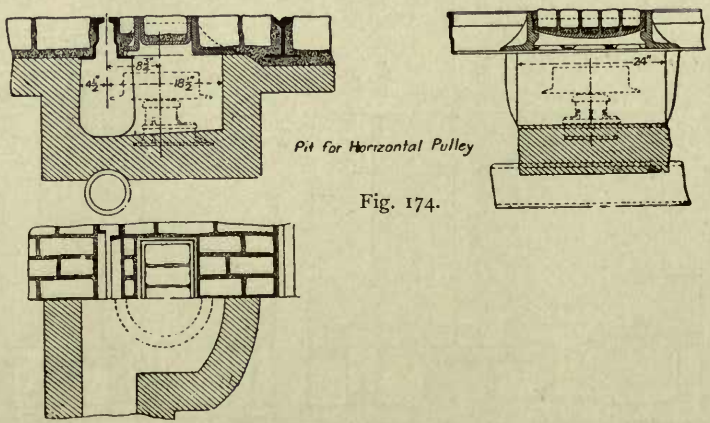


Fig. 174.

Figs. 172, 173 and 174. Edinburgh Cable Tramways.

40 lbs. per yard; they take a bearing upon the top edge of the yoke and are bolted thereto on each side of the yoke frame, so as to leave a slot about ¾ in. wide in the street surface. The cable runs on bearing pulleys 14 ins. diameter, carried on C. I. brackets bolted to the side walls of the tube, as shown in fig. 168. The pulleys are spaced at a distance of about 40 ft. apart; each is contained in an enlargement of the tube forming a pit or chamber extending to a depth of about 2 ft. 4 ins. below the street surface, with a manhole cover, giving an opening of about 18 ins. by 12 ins. for access to the pulley. On curved portions of the line the pulleys are rather larger, and placed at an angle of 45°, as shown in fig. 169.

Edinburgh Northern Tramways were opened in 1888. There are two separate routes, extending in all to a total length of about 2½ miles, nearly all double line. The structure of the track and tube differs in some respects from the Highgate line. The running rails are of a girder section and the slot beam is of a stronger form, and is carried on the yokes by a continuous rib taking a bearing of 2½ ins. below the street surface. It is bolted to the yokes horizontally through this rib and vertically by other bolts passing through projecting lugs on the yoke, as shown in fig. 170; in other respects its construction is very similar to the one above described. The tramways of Edinburgh were largely extended in the years 1896 and 1897, as a result of the purchase by the Corporation of the Co.'s interest, and the greater part of the horse lines were reconstructed as cable tramways by the Corporation, the total length of track at present being about 20 miles, nearly all being double lines. Generally speaking, the track rails are 6½ ins. deep, weighing 93 lbs. per yard, the slot beams weighing 48 lbs. per yard.

Fig. 171 shows the fish-plate, which is a Z form section, the horizontal flanges being secured by a peculiar hook-shaped bolt. Bolts of this form are also used in securing the slot beams to the yokes, which are very similar in form to those of the earlier tramways, except that they are of a heavier type. Other details showing fully the construction of the track and tube are shown in figs. 172-174. It will be seen that all the pulley pits are connected by a longitudinal pipe drain lying under the centre of the tube and connected of course at suitable intervals with the main drainage of the street.

The cable tramway at Douglas was constructed in 1896, its length is about 1½ miles, and is nearly all double line. The gauge is 3 ft. 0 ins., and the line is laid with girder rails weighing 76 lbs. to the yard. The slot beams are of the same section as used on the Edinburgh Northern Tramways, and weigh 48 lbs. per yard. The yokes are also of a similar structure and are placed 3 ft. 6 ins. apart. The tube is of concrete as usual, and a longitudinal drain is laid under each line for the effective drainage of the pulley pits.

The Birmingham Cable Tramway opened in 1887-8 is of a different type of structure to any of those above described.

The length is about 3 miles, all double track, the gauge 3 ft. 6 ins. The rails are girder section 7 ins. deep, weighing 98 lbs. per yard. The slot beams are also 7 ins. deep, and weigh about 60 lbs. to the yard; they are bolted to the upper surface of the inner member of the yoke and, therefore, overhang their points of support. To preserve the width of the slot the beams are tied back to the rails by peculiar T-headed tie bars, shown in detail in fig. 178—the running rails being also

Fig. 178.

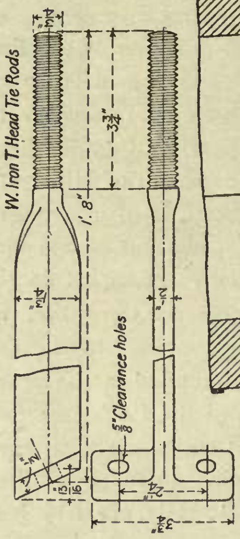


Fig. 179.

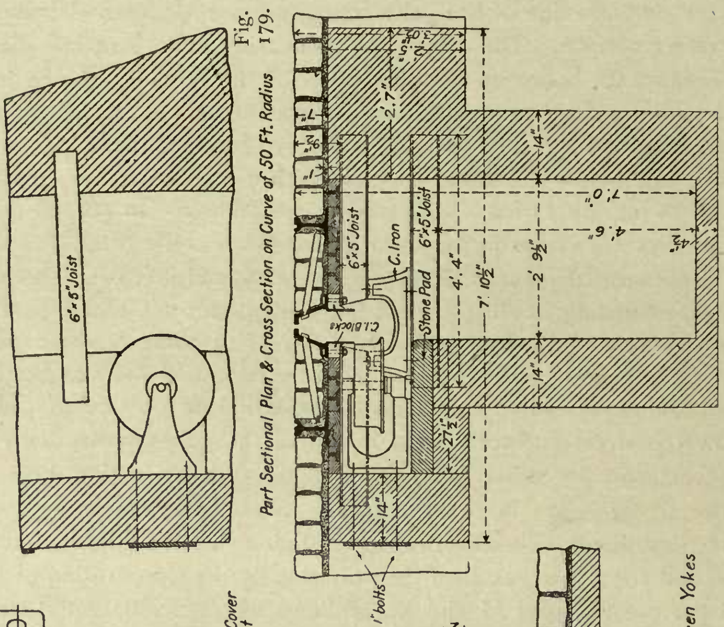


Fig. 180

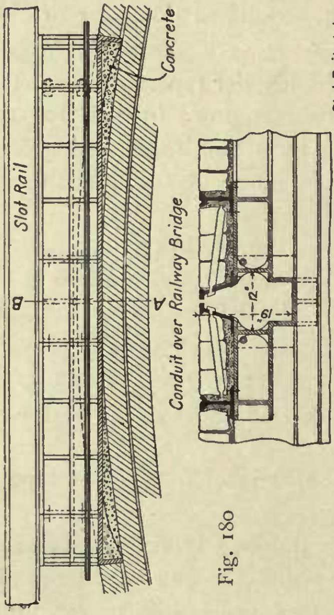


Fig. 177.

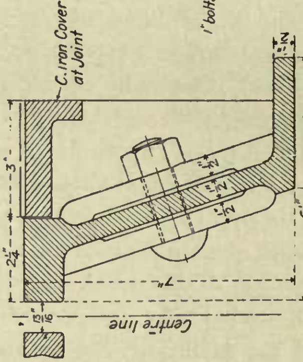


Fig. 176.

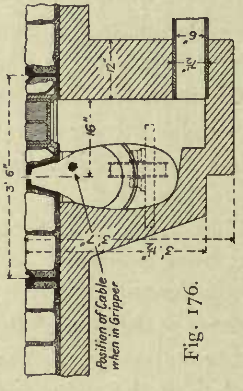
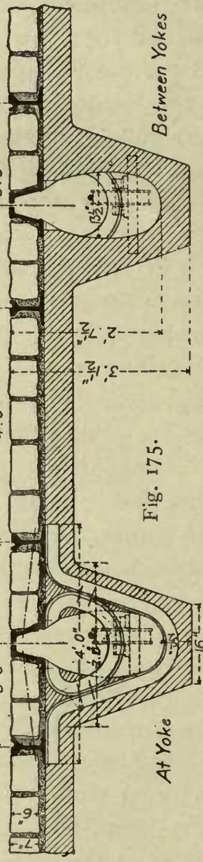


Fig. 175.



Figs. 175, 176, 177, 178, 179 and 180. Birmingham Cable Tramways.

bolted to the yokes to make this attachment effective. The yokes are made of T-shaped steel bars 4 ins. × 3 ins. × ½ in., as shown in fig. 175, forged and bent into shape and stiffened by an internal circular bow of the same section. The tie bars used at first in the construction are shown in figs. 179 and 180, but as these were not effective, they have been gradually replaced by the type shown in fig. 178. The slot beams are connected by flat fish-plates, as shown in fig. 177, and to prevent the fish-bolts causing difficulties with the pavement by projecting from the sloping surface of the outer fish-plate, each joint is covered by a cast iron cover-plate, carried on the horizontal flange of slot beam.

Owing to the great depth of the tube, viz., 2 ft. 8 ins. from the street surface, the pulleys require no enlargement in the form of a pit as when a shallow tube is used; a manhole, however, has to be constructed at the side of each pulley to admit of access for oiling, replacement, and repairs, and the bottom of each one of these recesses is carried down to a depth of 6 ins. below the bottom of the main tube and provided with a 6 ins. drain outlet. The pulleys are supported on independent cast iron frames built solidly into the walls of the tube.

The yokes are spaced 4 ft. apart, centre to centre, and the bottom curve for a depth of about 5 ins. only coincides with the internal face of the tube, which is built of concrete of the shape shown in the various drawings.

Fig. 179 shows the type of special work used on the sharp curve of 50 ft. radius near the City terminus. Owing to the sharp curvature the deflecting pulleys have to be placed very closely together, and a circular underground chamber is therefore constructed to avoid the necessity of numerous openings in the street surface.

Fig. 180 shows another piece of special construction on the adjacent railway bridge. One ring of the brick arches is cut away for the distance of about 9 ft. and a width of about 10 ins., and the gap thus made filled in by rectangular trough shaped castings, which preserve the continuity of the tube.

Some of the differences between the conduit as used for mechanical and as used for electrical traction have already been referred to. It may be useful now to give some account of the first British electrical tramway conduit. To the student of electrical engineering this work was of very great interest, and it was not without importance to the electrical industry, inasmuch as it was the first practical electric tramway in Britain. It did much to convince uninformed and non-enthusiastic persons that electric methods of supplying energy for tramway working were emerging from the "experimental stage."

At an exhibition held at Blackpool in 1884, one of the most popular exhibits was a length of electric tramway designed by Mr. Holroyd Smith. In many of its details the arrangements were only suitable for the purpose of a "side show," but the whole thing was so obviously full of potentialities that the Corporation of that town were persuaded to allow the principle to be used in the equipment of a couple of miles of tramway extending along the sea front. The importance of this decision on the part of the Corporation rests upon the fact that at this date, 1885, when the tramway was constructed, electric tramways were practically unknown. In the British Isles the only examples were the line upon the beach at Brighton, where the rails themselves were used as conductors, and the "light railway" from

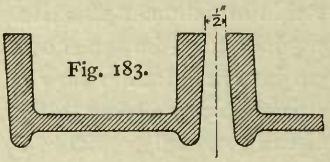
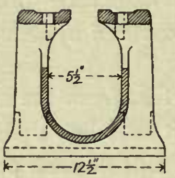


Fig. 183.



Section A B.

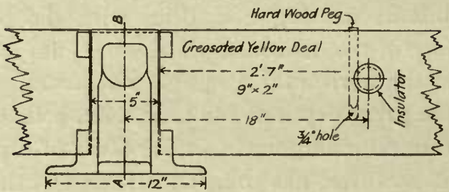


Fig. 181. Side Elevation of Yoke.

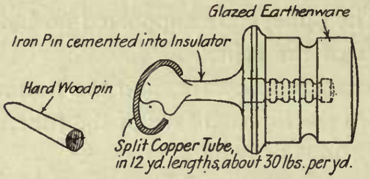


Fig. 184.

Glazed Earthenware
Iron Pin cemented into Insulator
Hard Wood pin
Split Copper Tube, in 12 yd. lengths, about 30 lbs. per yd.

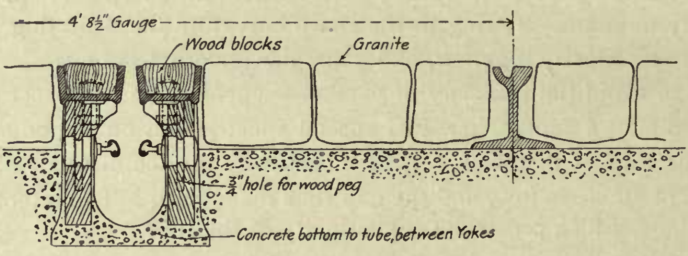


Fig. 182. Cross Section of Track.

Portrush to Giant's Causeway, where the "third rail" system was in use. On the Continent there was a line near Berlin where again the rails served as conductors, and another line in Austria where the overhead conductor was a slotted tube, in which ran a shuttle-shaped collector drawn along by the car. In America the overhead wire as now known had not yet been invented.

The alterations necessary to render the exhibition line suitable for use in a crowded public thoroughfare need not be specially referred to. A surface conductor was out of the question, so it was determined to place it underground in a slotted tube somewhat similar to a cable tramway. The form of tube adopted is shown in figs. 181 to 183. The cast iron yoke, shown in fig. 181, gave a tube about 5½ ins. wide and about 9 ins. deep, the upper part forming a bearing for the slot beams, shown in enlarged section fig. 183. These were rolled steel channel bars, the trough being filled in by wooden blocks forming part of the street surface. The yokes were spaced 3 ft. apart and set in concrete, which was brought up and tooled to form the bottom of the tube. The sides were formed by pieces of creosoted plank 9 ins. deep and 2 ins. thick, fitting in pockets formed in the sides of the yokes, but not bolted to them in any way, being held in position by the foundation of the granite pavement. An earthenware insulator was fixed in the centre of each one of these wooden pieces, and secured by a hard wood peg driven in from the top, as shown in figs. 181 and 182. The conductor consisted of a split copper tube carried upon and fastened to the insulators, as shown by fig. 184; the tubes were in lengths of 36 ft., which were connected to each other by internal counter-wedges of brass. In the original construction there were two conductors, as shown in fig. 182, but they acted as one electrically, being connected together at frequent intervals by U-shaped pieces of insulated cable. These conductors were connected with the positive pole of the dynamo, the return current being by the running rails, the joints of which were bonded by copper strips. This system of double conductor simplified matters at points and crossings, as the collector could always be kept in contact with one or other of them, and there was consequently no necessity for shooting through these parts by momentum. As a further advantage, the double conductor halved the resistance of this part of the circuit and so reduced the dead load on the engine.

These insulators caused trouble: every insulator is a point of leakage, and in this case the leakage was very great owing to the very large number and to the damp saline nature of their surroundings. There was no means of getting at them to tighten up or repair the wooden keys used to secure the copper conductors, except by taking off a length of the slot beam. Many of them were taken out, causing the conductors to sag and make contact with the sides or bottom of the tube, and so, after several years' working, every third yoke was taken out

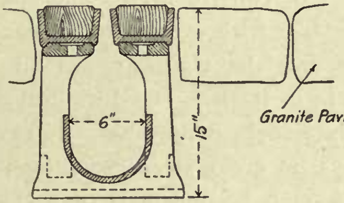


Fig. 185. Section through Yoke.

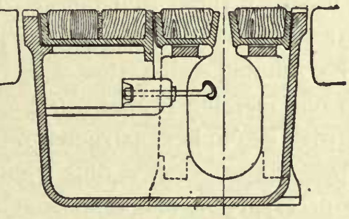


Fig. 186. Section through Insulator Box.

Blackpool—Lytham Road Section, 1895.

and replaced by one cast in the form of a box, as shown in fig. 186, with a lid in the street surface giving ready access to an improved form of insulator. These were fixed at one side of the tube only, as it was found that one conductor gave sufficient contact for supplying the current. This form was used throughout, and with a slightly enlarged tube, as shown in fig. 185, in the construction of the Lytham Road section laid in 1895.

A length of a further improved form of tube (Mapple's patent) was afterwards laid, in which the wood sides were done away with, the sides and bottom of the tube being formed of cast iron, with the slot beams hinged at the sides so that they could be turned aside entirely, thus exposing the whole of the interior of the tube. Little use was made of this, for the whole of the conduit was abandoned and overhead wires installed in its place. The reasons for this were not entirely due to the mechanical and electrical defects due to such a structure as has been described; besides these were the difficulties due to its location. Laid along the sea front upon a stormy coast, it was liable to frequent floodings from the sea, which often came over and filled it with sand. This entailed great expense in cleaning out, besides the annoyances and loss due to disturbance of traffic. In itself this would probably have been sufficient to cause its abandonment along the sea front, and being given up there it almost inevitably follows that it must be given up in other parts of the town where this difficulty was not experienced. To have kept a part only would have meant two separate services of cars, or else the expense and complications arising from having to equip every car with the apparatus necessary for working over both systems.

It is probable that the conduit in the London Electric Tramways will be accepted as a standard type for such work in future. It is the result of nearly 20 years' experience of endeavour to make a slotted tube conform to the conditions of a public street, and it is interesting to notice how little it differs in many of its general features from some of the earlier attempts in this direction. The improvement has come by careful design in details, always keeping in view the varied elements of the surrounding conditions.

A small part only of this experience has been gained in Britain. The cable tramways of Birmingham, Edinburgh, Brixton, Douglas, and the electric line at Blackpool, practically complete the list. Examples of greater number and greater variety are to be found on the American tramways, and there are some notable cases of electric conduits on the Continent.

There are here three well marked types of construction. The characteristic feature of the American tubes is a massive yoke with extensions on each side for carrying the running rails; thus the tube and the tramway are all connected together in one metallic framework complete in itself. The Birmingham tube is the only British example constructed on this model: it may have its origin in the American practice of constructing tramways on cross sleepers or ties; doubtless these were necessary at one time, and so having become part of a "standard" construction, they continued to be used when better construction of the roadway rendered them no longer necessary. The characteristic feature of the Continental conduits may be said to be the "side slot," that is, the tube is constructed under one of the running rails.

In the British examples of conduit work there are no side extensions of the yoke. With the one exception previously mentioned, the yoke is used to define and regulate the tube only, and the only connection between it and the running rails is a series of light tie bars somewhat similar in character to those used for preserving the gauge of an ordinary track. There is plenty of experience to show that these tie bars properly arranged are all that is necessary, and the absence of the yoke extensions saves cost and greatly facilitates the work of construction, especially upon curves and junctions.

The first section of the London Electric Tramways to be constructed was the Balham and Tooting route, opened in May, 1903, by His Royal Highness the

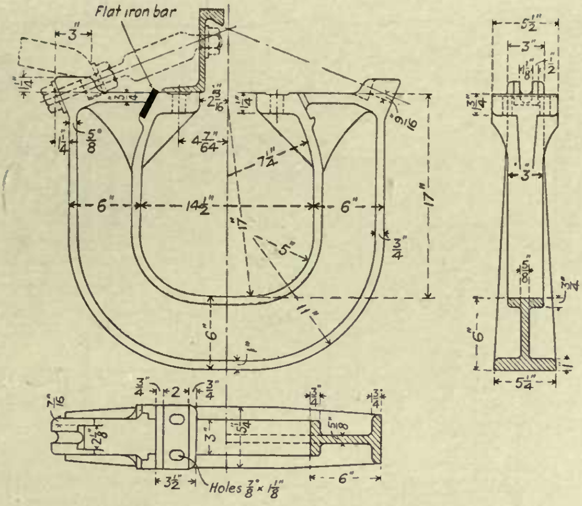


Fig. 187. Details of Yoke, London County Council Tramways.

Prince of Wales. As a matter of history it may be noted that Dr. A. B. W. Kennedy was instructed by the London County Council to report upon the whole subject of mechanical traction upon the tramways that had been acquired by the Council, and he prepared designs for an electric conduit, and contracts for construction were entered into with Messrs. J. G. White & Co. The original designs underwent modification in several particulars, and ultimately the line was constructed as shown in figs. 187 to 197, &c. The yoke shown in fig. 187 is of cast iron, and weighs about 152 lbs. These yokes are spaced 3 ft. 9 ins. apart. The slot beams shown in fig. 188 are bolted on the upper surface; they weigh 60 lbs. per yard, and are fixed so as to give a slot ¾ in. in width, and are retained in place by tie bars fixed in an angular position, as shown in fig. 187. The upper end of this tie bar is cranked so as to bring the screwed end into a horizontal position, and thereby give a square bearing for the nut on the inside. The lower end of the tie bar is screwed for a distance of about 6½ ins. and, as shown in fig. 187, it also serves to secure the tie bars controlling the running rail also.

The conductor bars are of mild steel of a modified T shape section, as shown in fig. 189, and weigh 22 lbs. per yard; they are carried by insulators bolted to the underside of the slot beams as shown in fig. 190. The conductor bar is carried in the forked end of a clip; the hole for the reception of the hanging bolt at the other end of this clip is made considerably larger than the diameter of that bolt and the hole through the upper washer is eccentric; this washer is finished on top in the shape of a nut, and it will therefore be seen that, if it be turned after the clip is in position, it must cause a movement of the conductor bar towards or from the centre line of slot to an extent depending upon the eccentricity of the hole. By this means the position of the conductor bar can be readily adjusted so as to bring it into its correct position in reference to the slot. These insulators are fixed in a recess formed in the concrete walls of the tube at intervals of 15 ft. along the track.

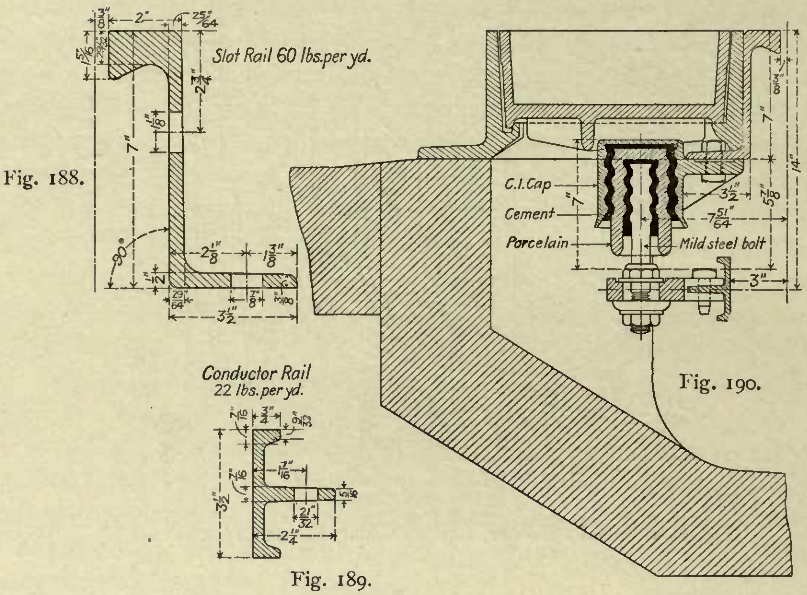


Fig. 188.

Fig. 189.

Fig. 190.

Figs. 188, 189, and 190. Details of Insulator and Insulator Pit, London County Council Tramways.

They are covered by a cast iron frame with moveable lid filled in with wood or granite blocks forming part of the street surface.

The main walls and bottom of the tube are formed of concrete shaped to conform to the inside of the yoke in the usual manner; as will be seen, however, on the cross section in fig. 193, the tip of this concrete wall is not protected by the bottom flange of the slot beam. To prevent it breaking away an iron bar about 3 ins. × ¾ in. section is placed across from yoke to yoke, being carried in a recess at each end formed in the casting, as shown on one side in fig. 187.

Fig. 191 is a general plan and cross section of the double track across a set of these insulator boxes, showing the arrangements made for draining the tubes. In every case these cross drains, laid at a slope of about 1 in 10, empty into a manhole constructed at the side of the track. This manhole acts also as a sump for the collection of such mud as may accumulate in the tube to be afterwards raked or washed out into the cross drains. The outlet from the sump is about 2 ft. from the bottom and is covered by a cast iron box which acts as a trap for preventing the passage of gas from the sewers. The box may be readily removed when necessary for cleaning the outlet to the sewers. In the more recently constructed electric conduits this arrangement of the drains has been improved, as shown by the plan in fig. 192, and the cross sections in figs. 193 and 194. The sump has been placed in the centre between the two tracks, and it is obvious that the arrangement gives far more ready access to the tube, besides taking up less space under the roadway.

The running rails on the first contracts are as shown in fig. 195, being a 7 ins. girder rail weighing about 102 lbs. per yard. The joint is one of the earliest and not the most efficient of the "Dicker" series of joints, the peculiarity of which is

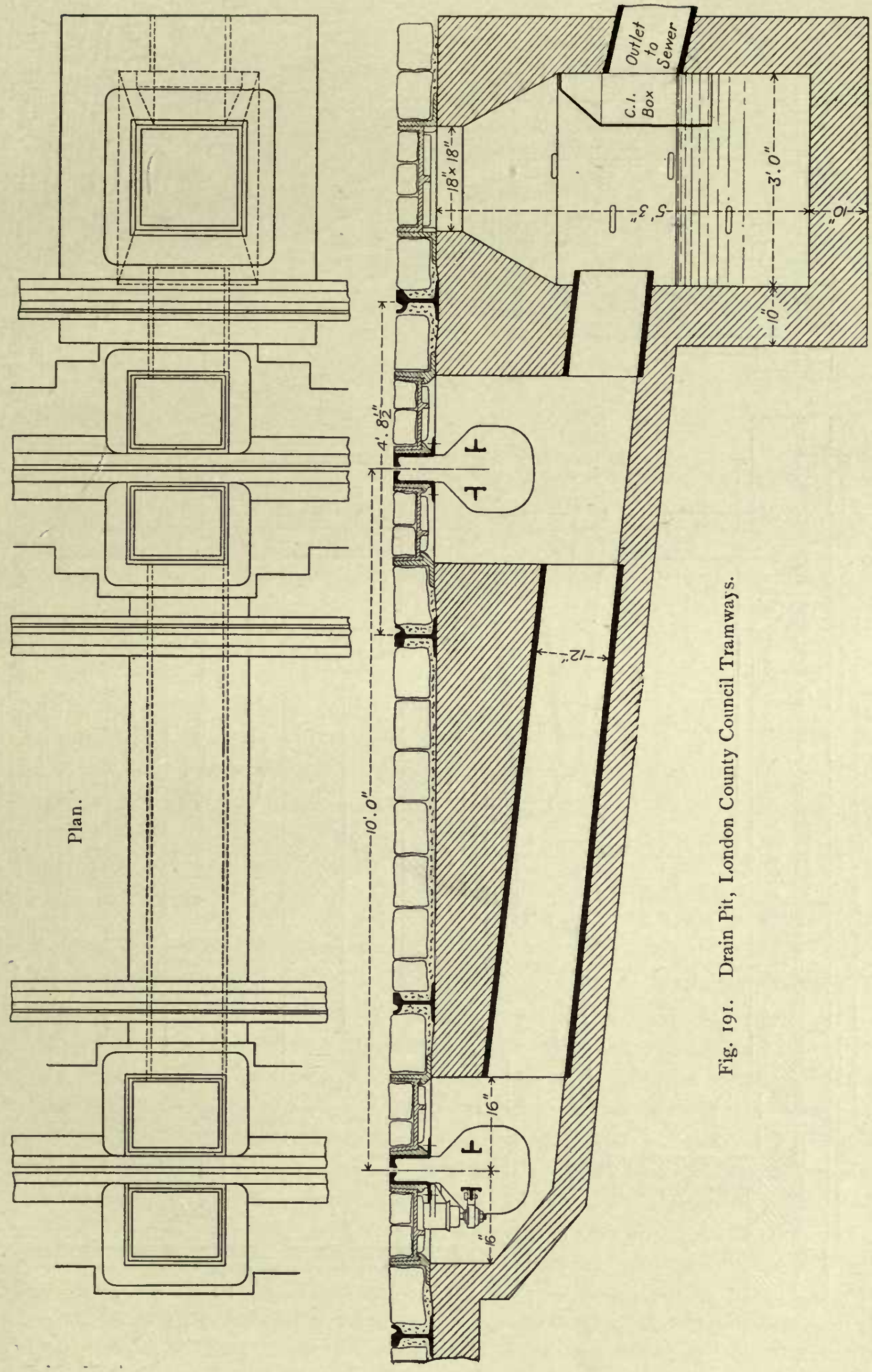


Fig. 191. Drain Pit, London County Council Tramways.

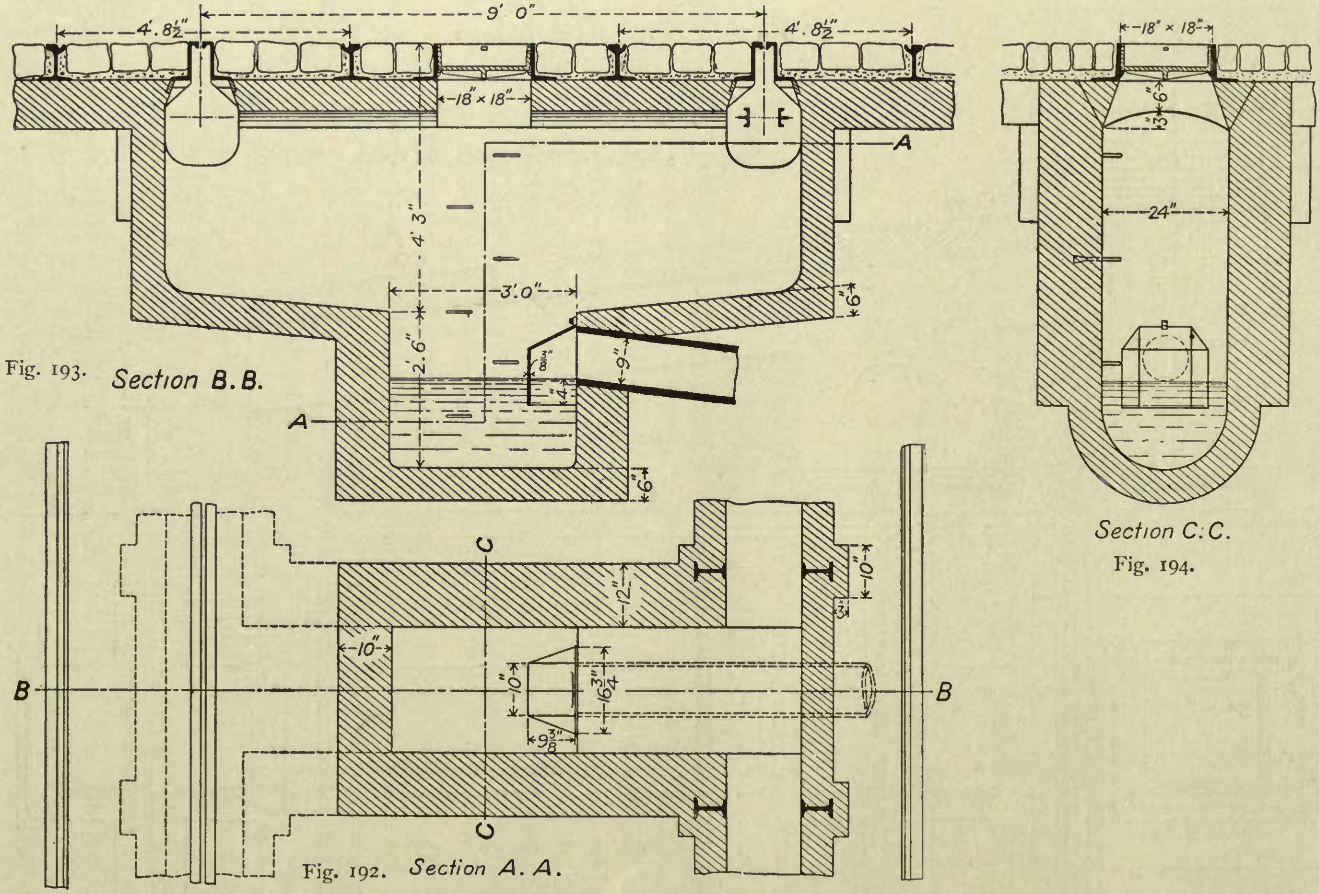


Fig. 193. Section B.B.

Section C:C.

Fig. 194.

Fig. 192. Section A. A.

Figs. 192, 193 and 194. Drain Pit, with Sump, London County Council Tramways.

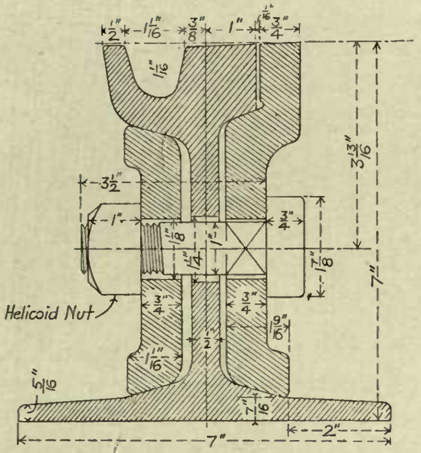


Fig. 195. Section of Running Rail, London County Council Tramways.

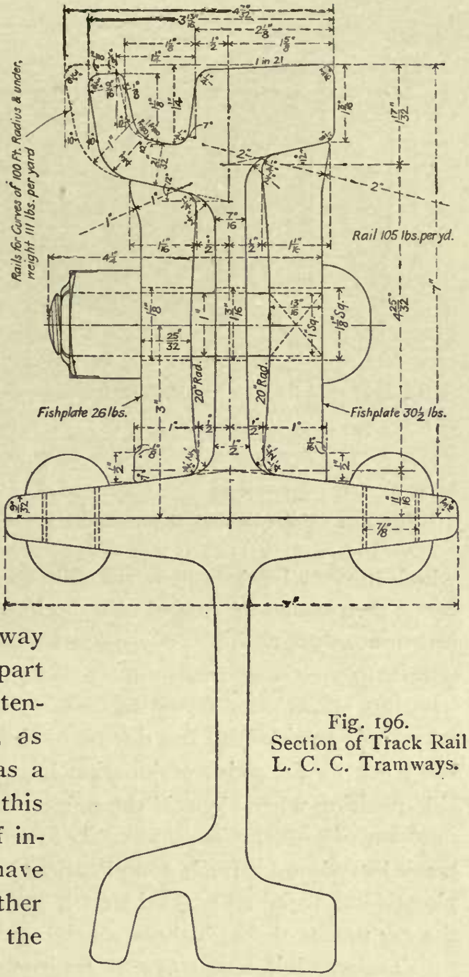


Fig. 196. Section of Track Rail L. C. C. Tramways.

that a part of the head of the rail is cut away and a fish-plate extended upwards to form part of the wearing surface. In the latter extensions the B S No. 4 rail and fish-plates, as shown in fig. 196, have been used, and as a check upon the well-known inefficiency of this form of joint on street tramways pieces of inverted rails or "anchors" about 2 ft. long have been fixed under the abutting rails; another similar piece has also been fixed under the centre of each rail.

Bournemouth Conduit Tramways.—

The central sections of the Bournemouth Corporation Tramways furnish the only example in Britain of what has been referred to as the Continental method. One of the slot beams acts as a running rail, the other forms the guard flange and the slot represents the groove. From a vehicle owner's point of view this method of constructing a conduit tramway presents manifest advantages; there are only two lines of rails instead of three, there are only four junctions between rail and pavement instead of six, and it is well known that the line of this junction is the place where obstructions and danger to ordinary wheeled vehicles is likely to arise. From a tramway engineer's point of view the arrangement also possesses certain advantages, but not of any well marked character, the chief, perhaps, being that it is rather more economical in construction. It is equally convenient in working the cars, and the plough conveying the energy from the underground conductors is well in sight instead of being covered by the body of the car; the chief objection to this arrangement is undoubtedly the difficulty it introduces in connection with the points

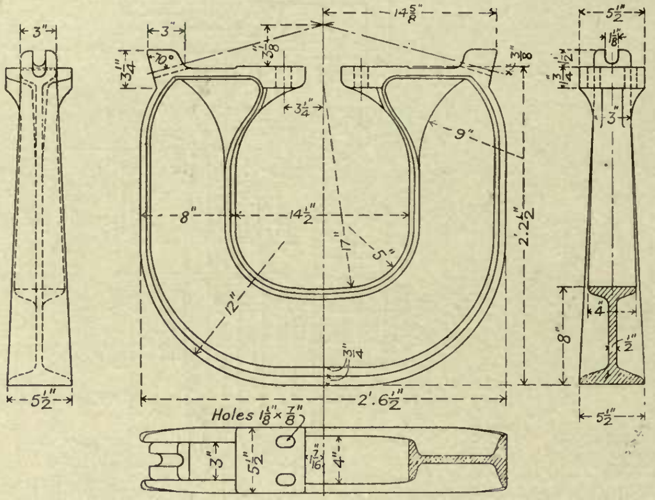


Fig. 197. Yoke Details, Bournemouth Corporation Tramways.

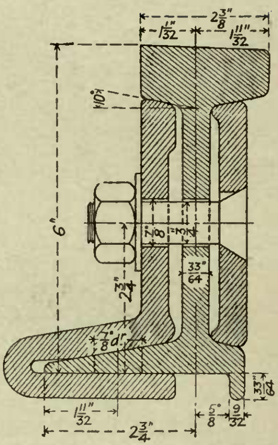


Fig. 198. Slot Beam and Joint, Bournemouth Cor. Tramways.

which have to be designed, not only for deflecting the plough sideways, but also to carry the ponderous weight of a modern electric car. At these points the two tubes blend into one, and in the angle between them it is practically impossible to make a satisfactory arrangement for carrying this weight on a slender cantilever overhanging so far its supporting base. This is an old difficulty, and on these tramways it is avoided by the device of deflecting the slot and tube into the centre of the track as the point of junction is approached, and leading it back again to the side position when clear of the points, crossings, and other special works which the junction of two tracks necessarily involves. This way of avoiding difficulty in the track introduces a fresh complication in the equipment of the car, inasmuch as the plough has to be so carried that it is capable of automatic lateral displacement as the car passes through these special sections of the route.

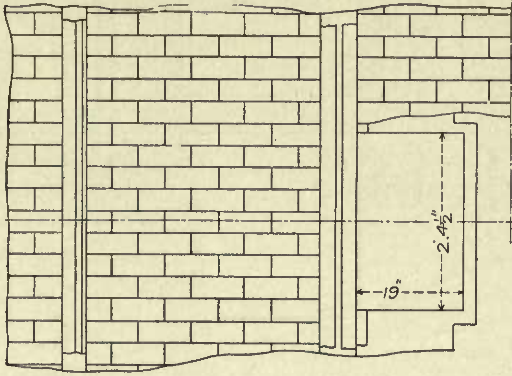
The conduit tramways at Bournemouth are also remarkable for the crooked and tortuous nature, both horizontally and vertically, of the thoroughfares through which they pass, and which has probably added something to the difficulties entailed in the work; these peculiarities of the track, however, have no effect upon the operations of the cars.

The cast iron yoke is a larger and heavier structure than the one described in connection with the London C. C. tramways. Internally its dimensions are the same, but its frame is 8 ins. wide instead of 6 ins., and the total weight is about 200 lbs. The arrangements for securing and holding the slot beams in position are also similar to those before described.

The slot beams are shown in fig. 198, and differ in important respects from the London beams, inasmuch as the outer one of the pair has to serve as a running rail. The beam is formed somewhat in the shape of a girder rail 6 ins. deep, minus the groove, with a very small flange at one side turned down to form a drip.

The internal fish-plate is an ordinary flat bar section, the external plate has its bottom member turned round so as to clasp the outside flange of the slot beam in the same way as the fish-plates in later forms of the Dicker joint. The fish-bolts

Fig. 199.



Part Plan of Track showing lid over Insulator Box

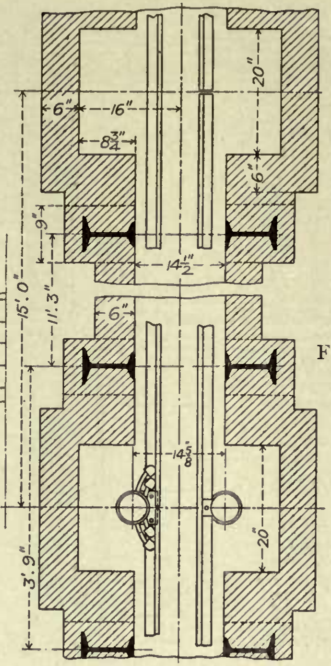
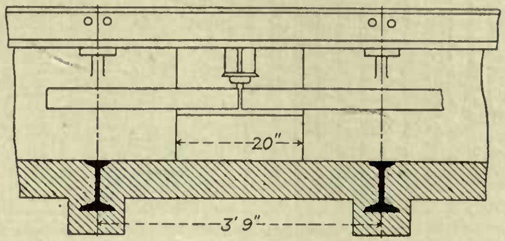


Fig. 200.

Sectional Plan of Insulator Boxes

Fig. 203.



Section A. A.

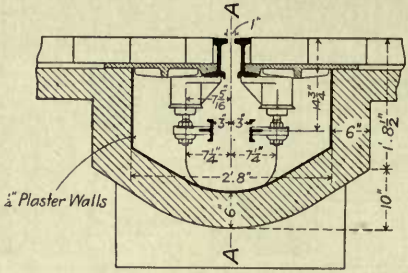
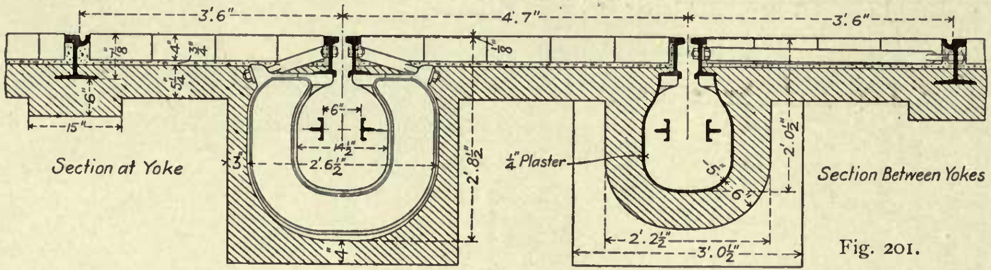


Fig. 202.

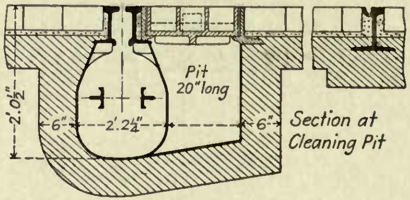
Section through Insulator Pit



Section at Yoke

Section Between Yokes

Fig. 201.



Section at Cleaning Pit

Fig. 204.

Figs. 199, 200, 201, 202, 203, and 204. Details of Insulator Boxes, Bournemouth Corporation Tramways.

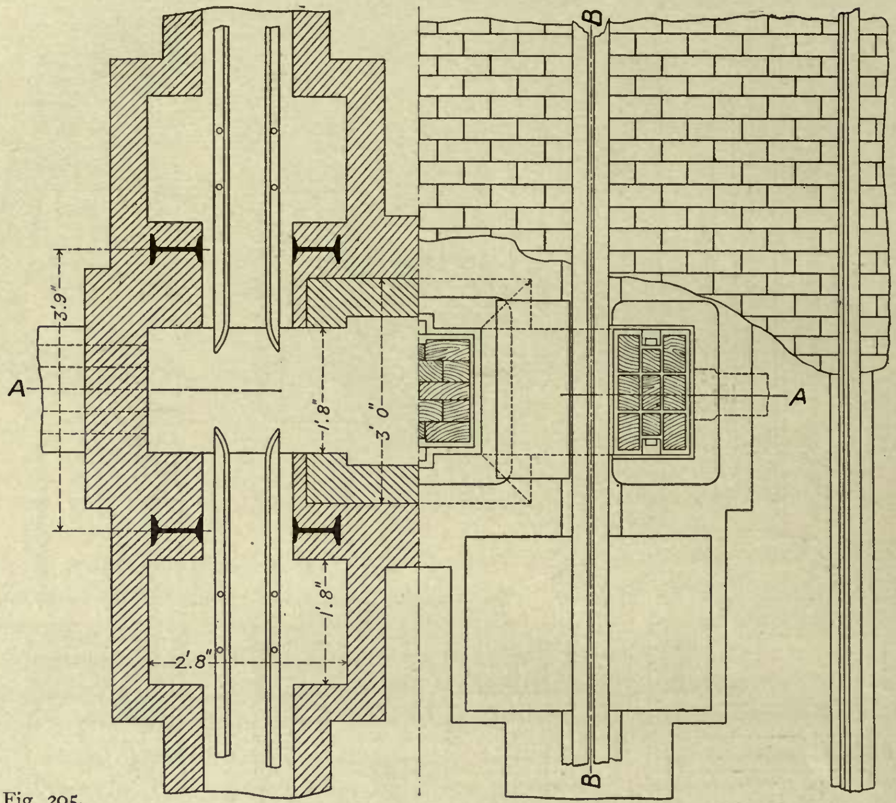
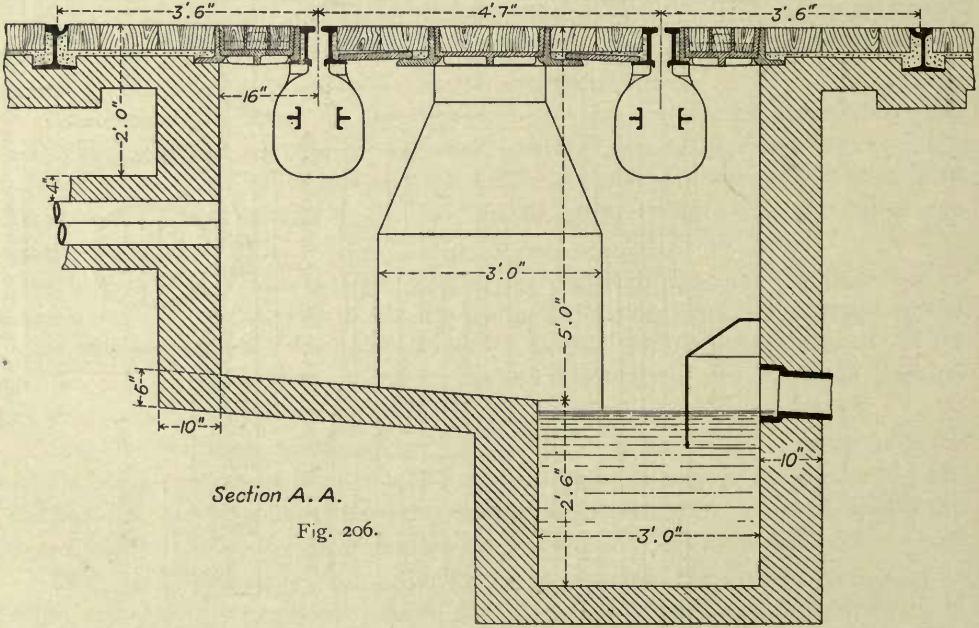


Fig. 205.

Part Sectional Plan & Part Plan of Section Insulator & Drain Pit



Section A. A.

Fig. 206.

Figs. 205 and 206. Section of Insulator and Drain Pit, Bournemouth Corporation Tramways.

have countersunk heads flush with the inside fish-plate, and are prevented from turning in screwing up by a nib fitting into a slot formed in the fish-plate hole.

The conductor rails are exactly the same as in the London C. C. work, and are carried by insulators bolted in the same way to the underside of the slot beam. These insulators are fixed in side pockets formed in the concrete tube as before, but instead of being covered by a cast iron frame with a moveable lid, they are covered by a flat cast iron plate, which is covered by the wood pavement of the street, so that no indication of its presence is apparent on the street surface as shown in fig. 202. These beams are fixed so as to give a slot 1 in. wide, this being the minimum width for the free working of the wheel flanges; they are kept in position by oblique tie bars at every yoke as shown in fig. 201.

Figs. 199 and 200 show in plan the general arrangement of tube, yokes, conductor bars, and insulator chambers.

Fig. 201 shows a general cross section through the track, showing at one place the arrangement at a yoke, in another the concrete tube between yokes. Fig. 204 shows the cross section through one of the cleaning pits where the arrangement is very similar to that adopted at an insulator chamber, except that it is covered by a cast iron frame with an ordinary manhole cover. Figs. 202 and 203 show respectively a cross section and a longitudinal section through an insulating chamber.

The general arrangement of track and tube at a section insulator is shown in plan partly in section in fig. 205, the insulator between the two sections being simply an air gap about a foot wide. Each conductor bar at this point terminates

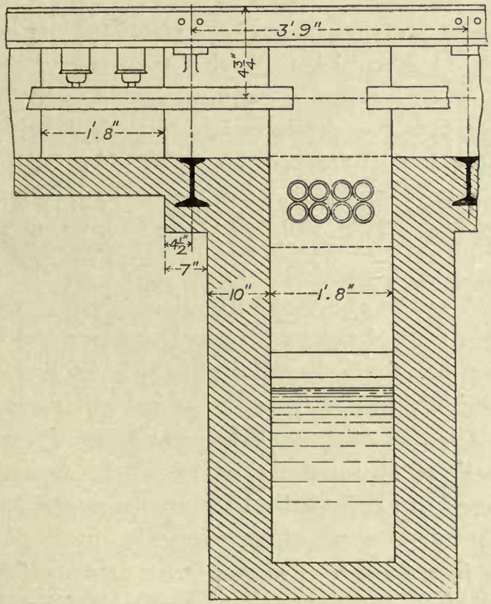


Fig. 207. Section on B B (fig. 205).

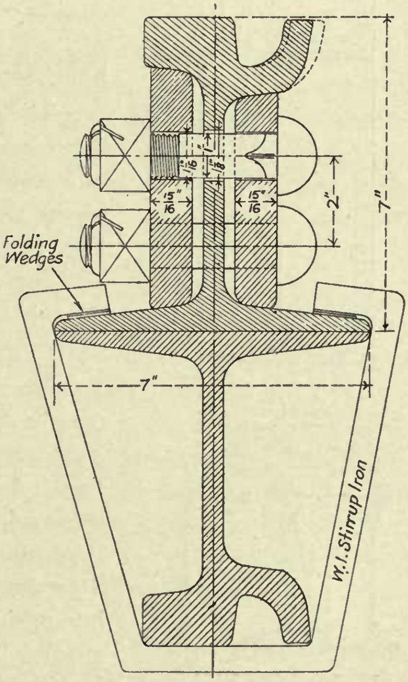


Fig. 208. Section of Rail, Bournemouth.

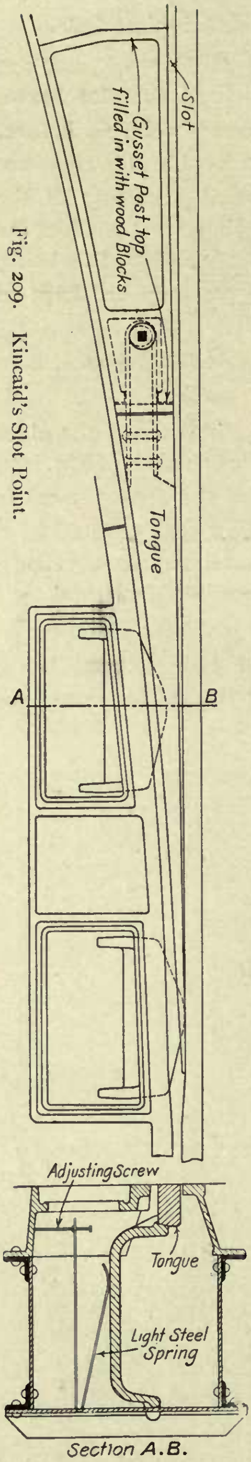


Fig. 209. Kincaid's Slot Point.

with a curved splayed end, so that as the plough leaves one section it is sure of entering the next. To give the requisite stability to the free ends of these conductor bars each is carried upon two insulators in the next adjacent insulator chamber. Fig. 206 is a cross section of the track through the junction between two adjacent sections, and shows the arrangement of cleaning pit, sump, and outlet to drain very similar to those already described in the case of the London C. C. Fig. 207 is a longitudinal section through the conduit and drainage sump, and shows the feeder ducts for reception of cables to be connected to each of the eight conductor bars terminating in this pit. This section also shows the double suspension for the free ends of conductor bars.

The ordinary track rails are shown in fig. 208. The fish-bolts are staggered in position as at Glasgow with the object of bringing the pressure to bear more directly upon the bearing surfaces. The piece of inverted rail used as an anchor at the joint is fastened in position by a cramp or stirrup formed of a strong square bar bent into the shape shown, and fixed in place by means of folding wedges driven in on the upper side of the foot of the rail. Intermediate anchors are also fixed along the rail in same manner.

Cable Conduit Points.—

The point at a junction has always presented one of the chief mechanical difficulties met with in the construction of a conduit tramway, and many examples could be given of the ways in which this difficulty has been dealt with. Fig. 209 shows the chief features of a slot point on the Birmingham Cable Tramways, as designed by Messrs. Kincaid & Pritchard, in 1887, and still in use on some parts of the line.

The pivoted end of the tongue is placed in a recess cast in the upper part of the gusset piece; its free end is supported on two peculiarly shaped tumblers shown in section. As the gripper passes through the point it pushes these aside one after the other so that one or other of them is always in position to support this end of the tongue. As at first designed, it was intended to return these tumblers into position after the passage of the gripper by means of a weight, but the light flat spring shown in the cross section has been found amply sufficient for the purpose. The pin on which the point tongue rocks is formed into an eccentric

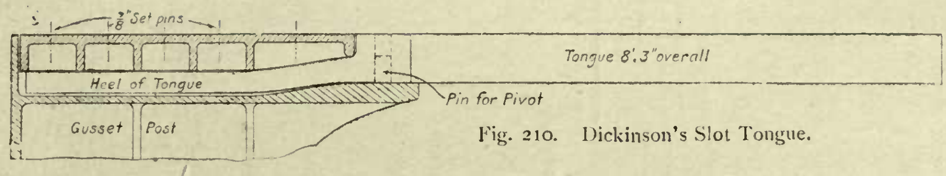


Fig. 210. Dickinson's Slot Tongue.

capable of being moved by a key inserted at the street surface, and by these means the tongue is thrown over to one side or the other without interfering with the action of the tumblers supporting its free end.

Fig. 210 shows an improvement introduced later on by Mr. Alfred Dickinson.

The upper part of the gusset piece is strengthened and brought forward and a pin fixed into it forms a pivot round which the tongue moves. The back end of the tongue is flattened and carried backwards to the full extent of the gusset post, it is then covered by a checkered iron plate on the street surface, the sides of which are prolongations of the corresponding exposed parts of the tongue, and so form the edges of the slot. This plate is securely fastened down to the gusset post by a row of screwed set pins along each edge, leaving the heel of the tongue freely moveable below it. The front end of the tongue thus forms a cantilever overhanging the tip of the gusset post and anchored down at the heel by the checkered plate before mentioned. On a crossover road where the point is always required to act in one direction only a light coil spring acting on one side of the heel of the tongue suffices to keep it in its proper position.

On the Edinburgh Cable Tramways a more elaborate construction is adopted, as shown in fig. 211.

The tongue is double. The fixed portion is a massive casting overhanging the gusset piece for a distance of about 3 ft. 9 ins. The moveable portion is supported by, and works upon this, being pinned down by a bolt at the heel and overhanging the fixed tongue for a distance of about 22 ins. To support this tongue under passing traffic, and to lock the same in position when thrown over to one side or the other, there is a peculiar arrangement of latches provided as shown on cross section D D, fig. 211.

Each latch is fixed in a cast iron box bolted to the outside of the slot beam, and projecting through a long rectangular hole in that beam forms a bearing for the end of the tongue. On the underside of the tongue there is formed a circular recess with a radius equal to the length of the projecting latch. A nib on the top of the latch engages with this circular groove and holds the tongue securely in position. There is nothing automatic about either tongue or latch. The tongue has to be thrown over by an ordinary point bar and then the latch for securing it is the opposite side of the point working in a groove turned in the opposite direction turned into position by means of a properly shaped key. A similar latch is fixed on for securing the tongue when thrown over to open the other slot.

Electric Conduit Points.—

The arrangement of points on the modern electric conduits is much more elaborate than those described in connection with the cable system; both track and

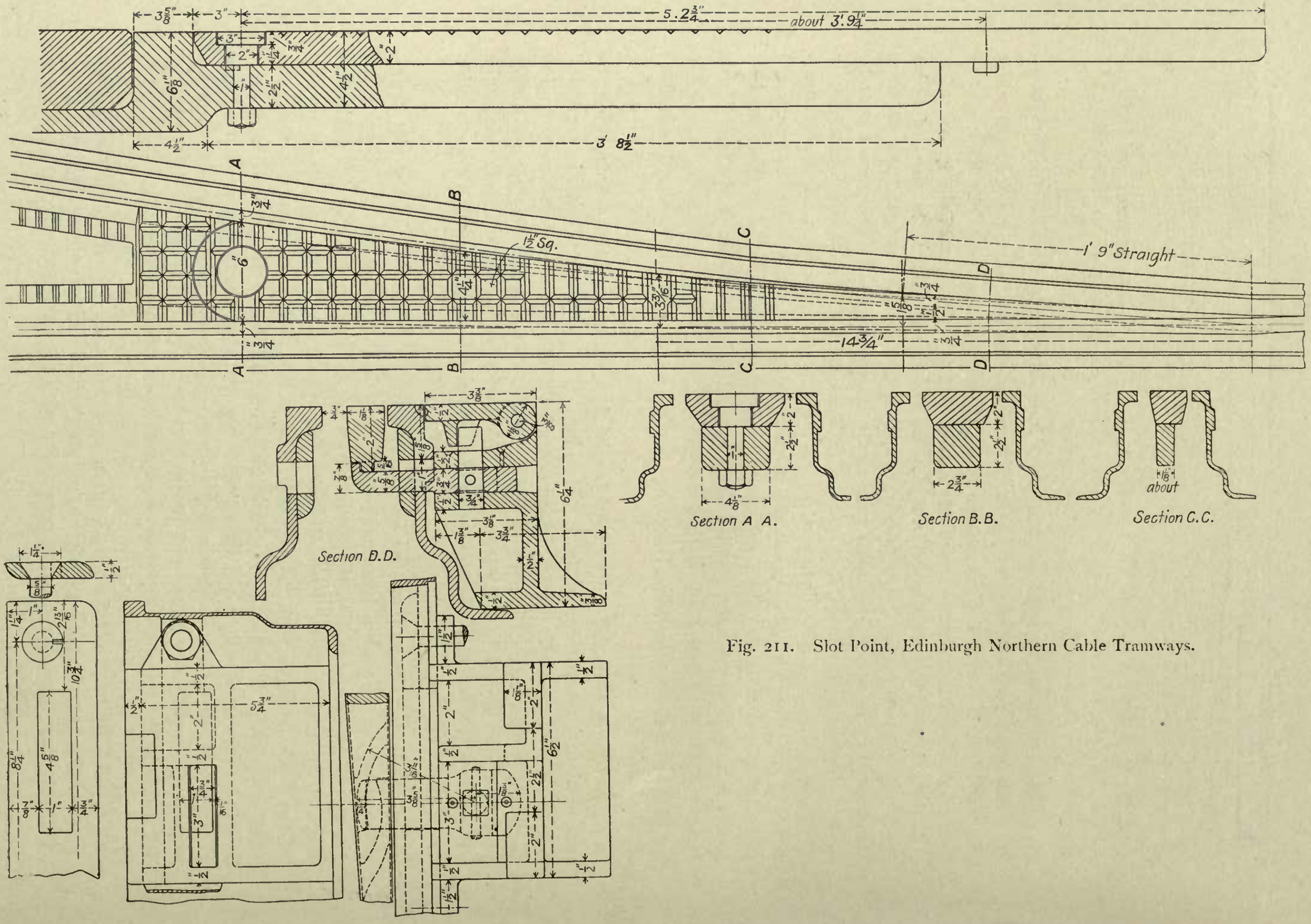


Fig. 211. Slot Point, Edinburgh Northern Cable Tramways.

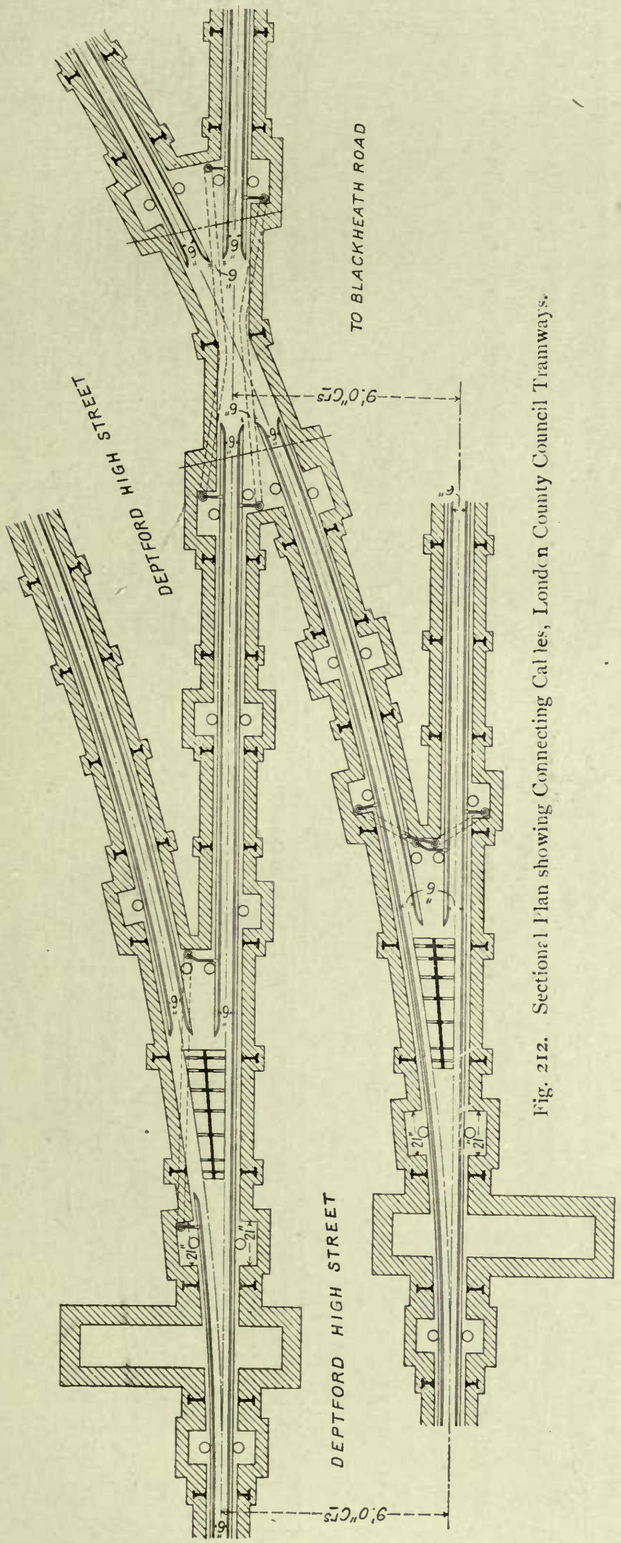


Fig. 212. Sectional Plan showing Connecting Cables, London County Council Tramways.

slot points are connected together by a system of links and levers in such a way that they all move together.

On the London County Council Tramways both of the running rails are furnished with moveable tongues. These points are similar to those of an ordinary tramway (and have already been described) excepting so far as affects the means of working them together. The general arrangement of the connections between these parts and the chambers that have to be constructed underground to contain this mechanism will perhaps be best understood by reference to figs. 212-213.

Fig. 212 is a horizontal section through the tubes at the junction in Deptford High Street. It shows the arrangement of conductors necessary under such circumstances and the gaps that have to be made in them when one tube runs into or crosses another one. It must be remembered that these conductors are of opposite polarity, and that this polarity may have to be sometimes reversed; it therefore follows that it is only under exceptional circumstances that the conductors could be joined together. The plan shows also the insulated cable connections between the broken conductors where they do not form the terminus of a separately-fed section.

The general arrangement of the yokes and concrete walls of the tube is also shown upon this plan, also the pits for containing the mechanism for working the

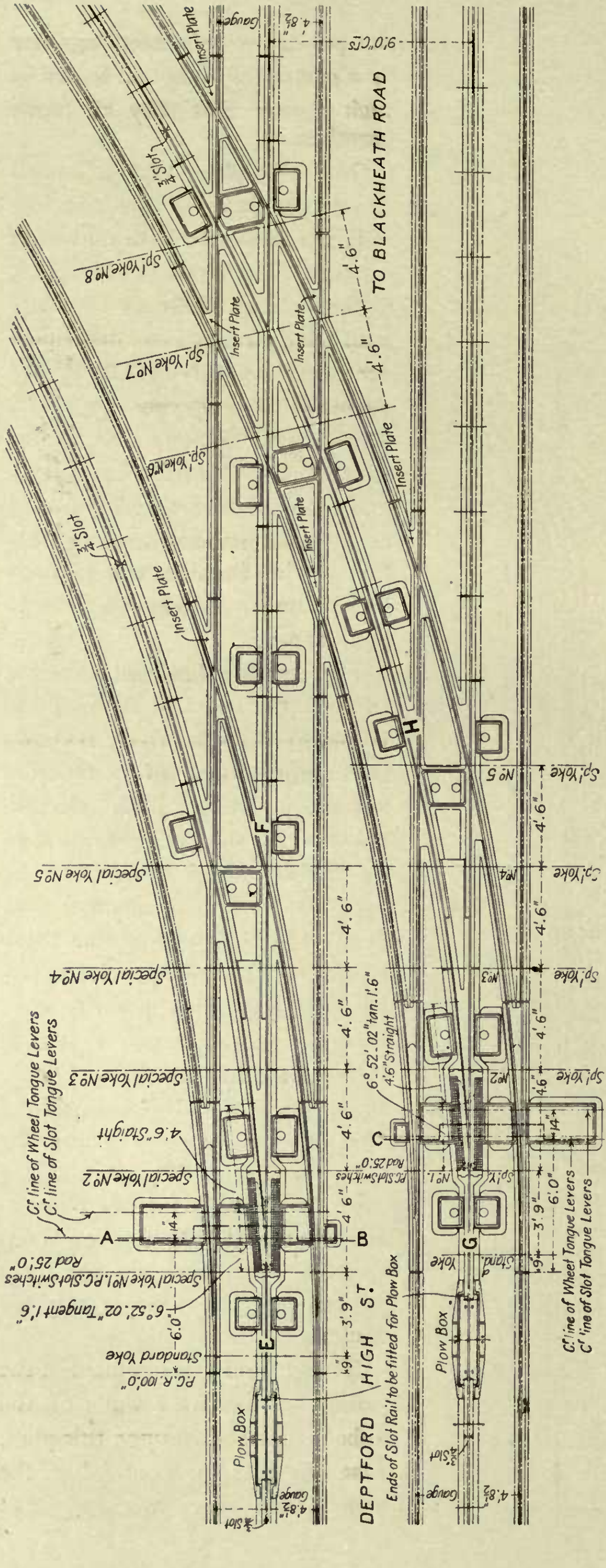


Fig. 213. General Plan of Junction, London County Council Tramways.

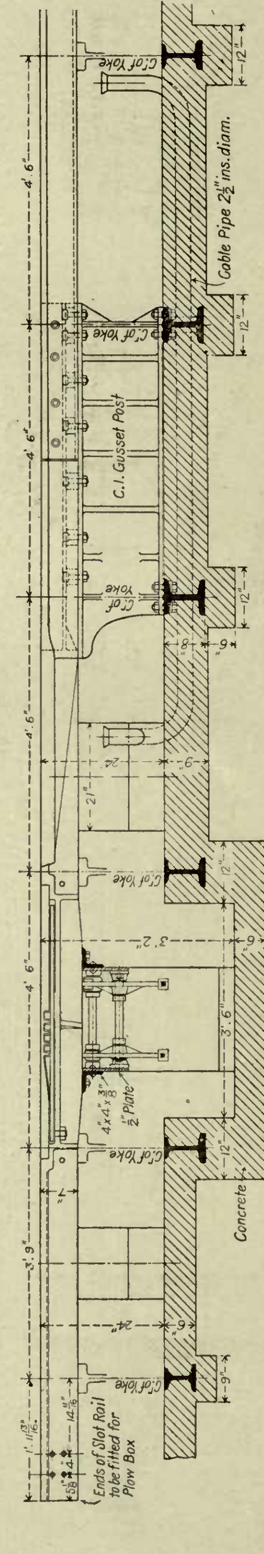


Fig. 214. Section E F (fig. 210) Through Straight Track, London County Council Tramways.

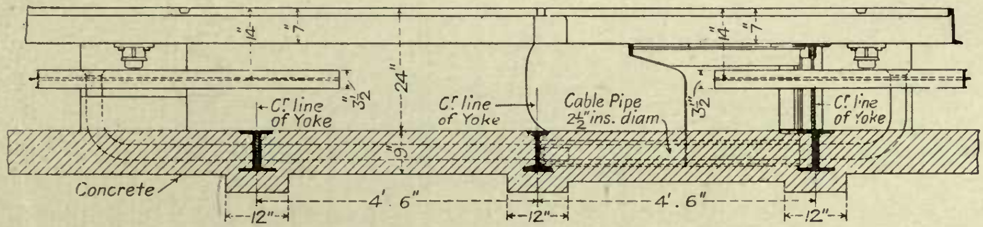


Fig. 215. Section on G H (fig. 210) Through Crossing.

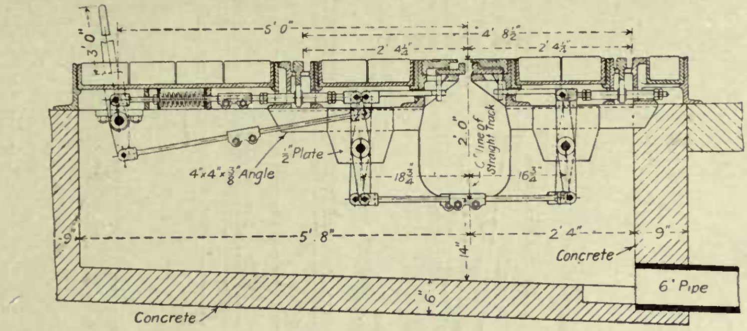


Fig. 216. Section on A B (fig. 210).

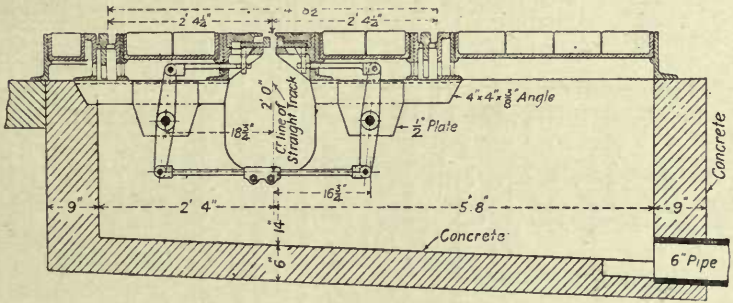


Fig. 217. Section on C D (fig. 210).

moveable points, and the position of the massive gusset posts bolted to two special yokes and required for carrying the long overhanging tongue between the two converging slots in the street surface.

Fig. 213 is the surface plan of this junction. The extent of the special work which is carried out in steel castings is shown by the full lines, dot-and-dash lines indicating rails and slot beams of the ordinary rolled sections.

Fig. 214 is a longitudinal section along centre line of the straight track through the junction.

Fig. 215 is a longitudinal section on the centre line G H of the curved track through the crossing.

Fig. 216 is a section on the line A B through pit and transversely across the tube, passing through the moveable track points also.

It will be seen that the moveable tongues of all three points are connected together by a system of adjustable links and levers, so arranged as to be kept over by a spring in the one position, being thrown over to the other side as required

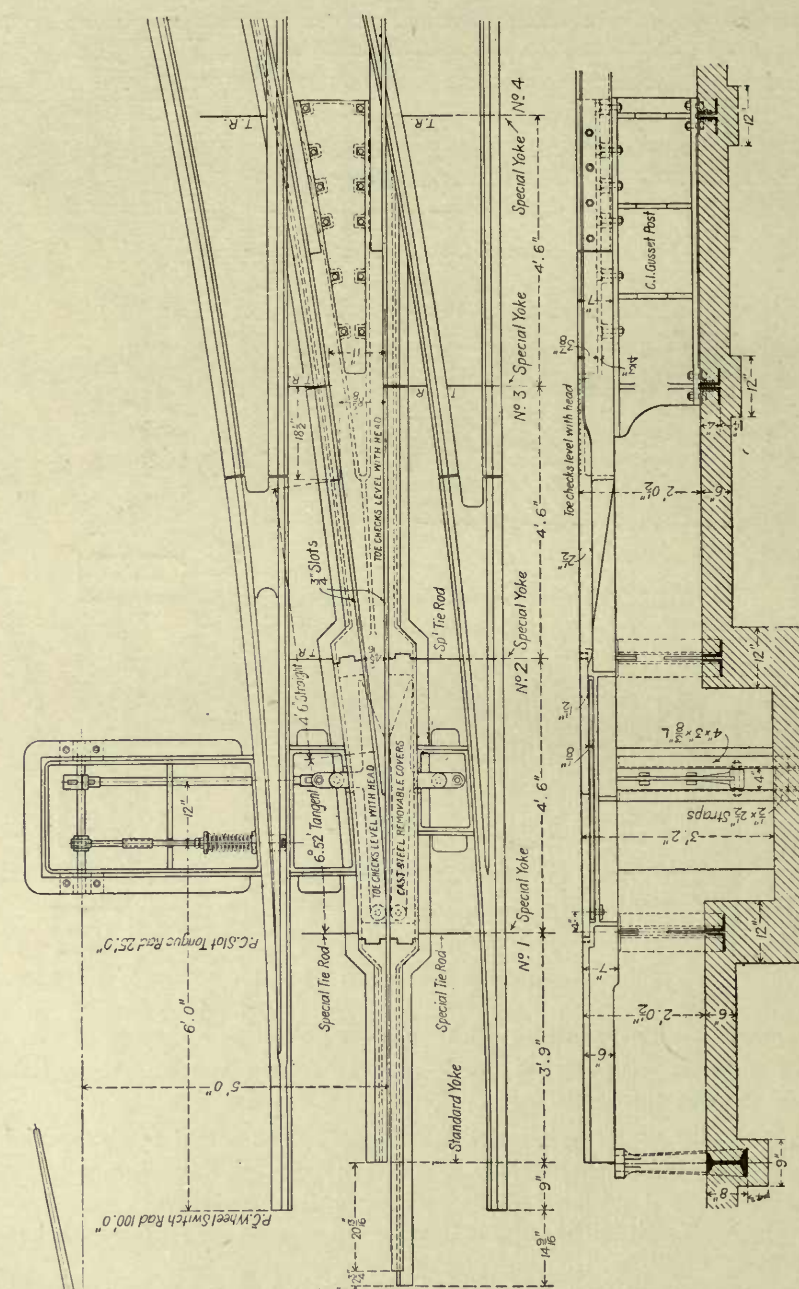


Fig. 218. Switch Operating Mechanism, Bournemouth Corporation Trams.

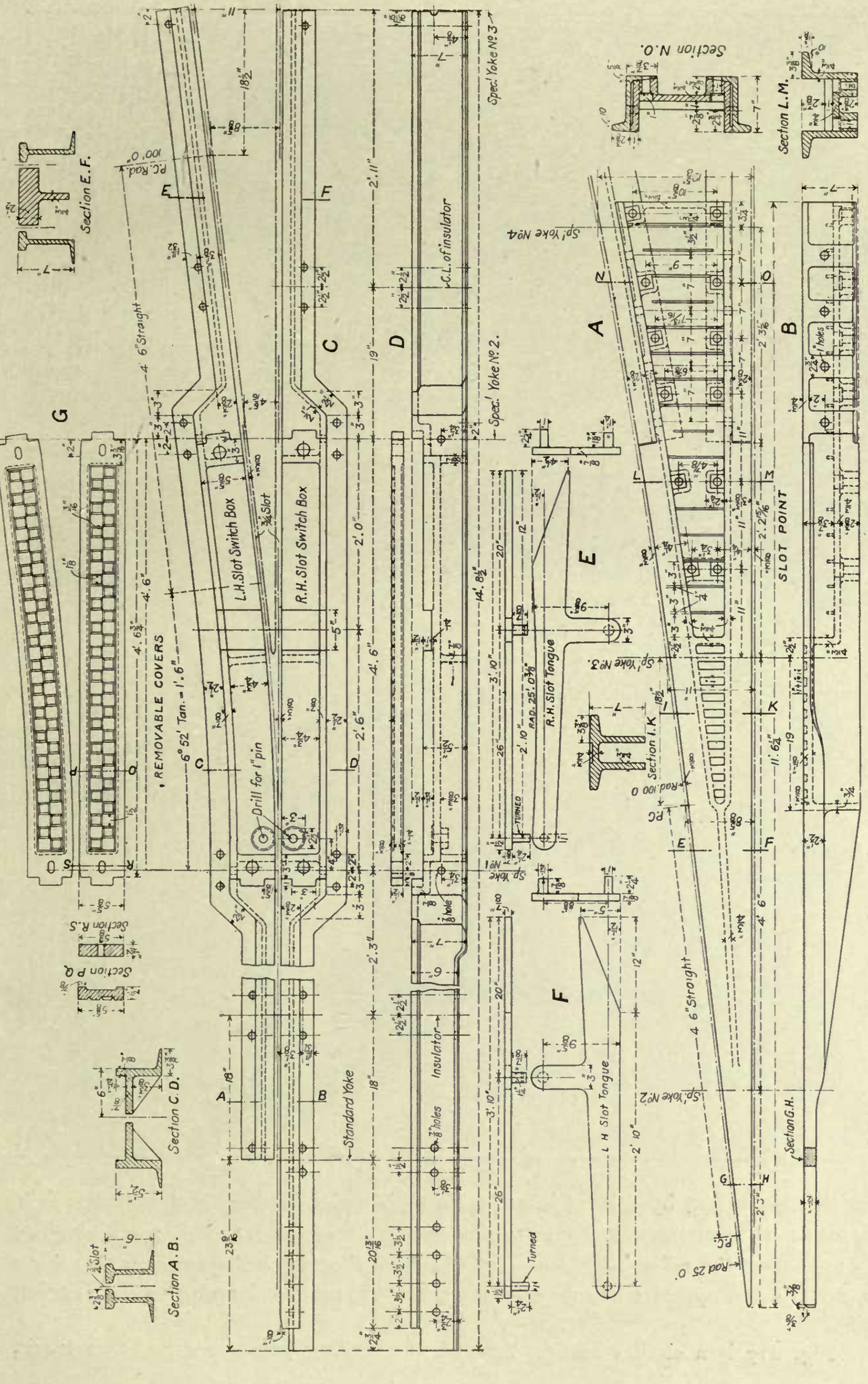


Fig. 219. Details of Slot, Switch Boxes, Covers, Tongues, and Slot Point, Bournemouth Corporation Tramways.

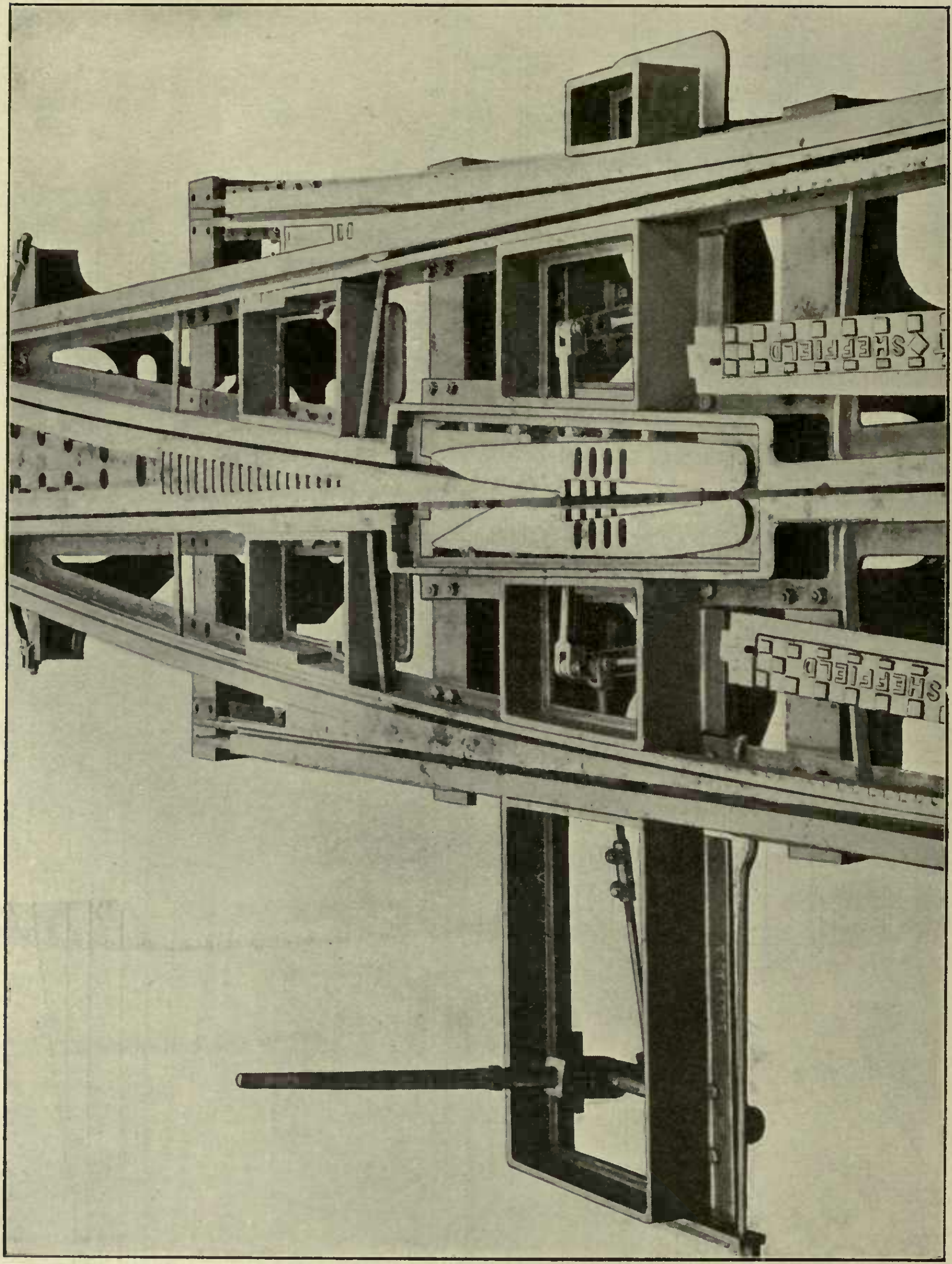


Fig. 220. Points and Crossings for London County Council Tramways, made by Hadfield's.

against this spring by a lever inserted through a slot in the street surface. The moveable parts of the slot point are not on the street surface, they are pivoted at the toe end of the point instead of at the heel, so that when thrown over they have to move in the opposite direction to the moveable parts belonging to the running rails.

Fig. 217 is a similar section through the trailing points on the other track,

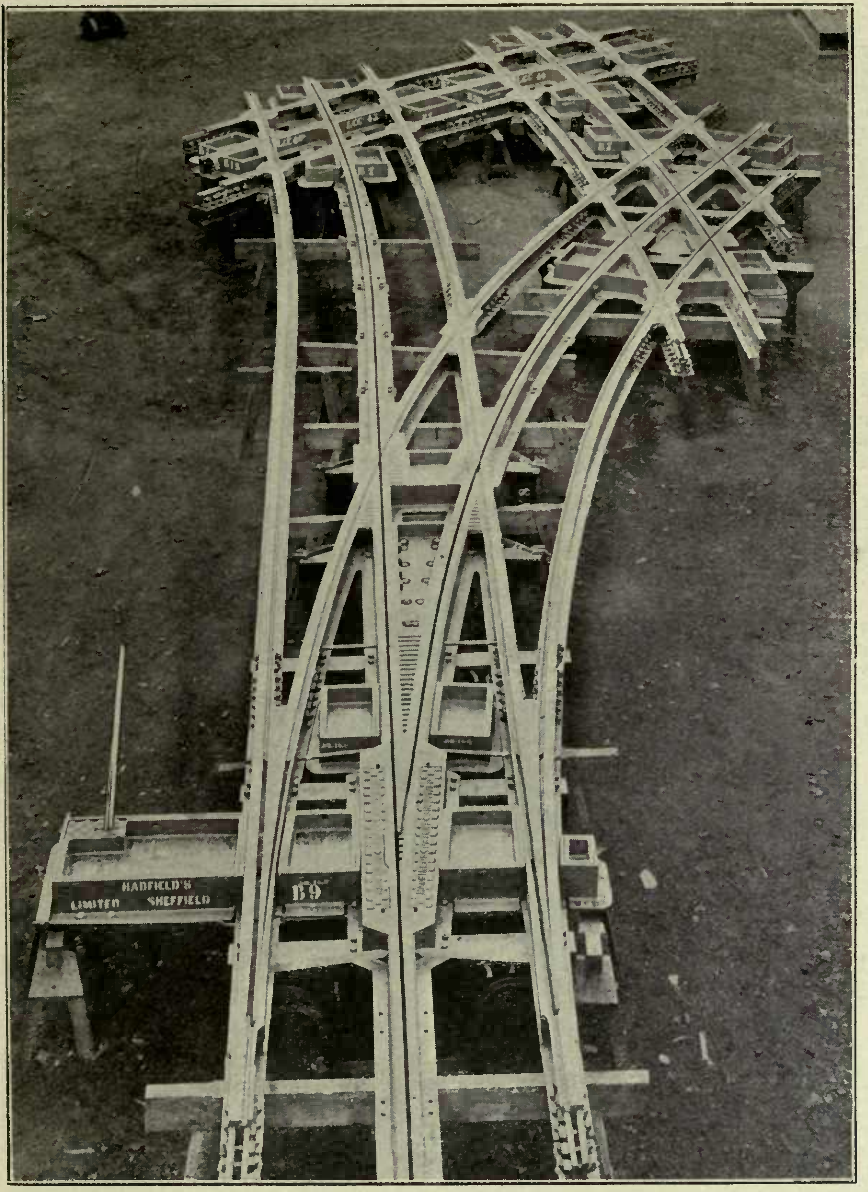


Fig. 221. Points and Crossings for London County Council Tramways, made by Hadfield's.

but shows the levers and connecting pieces on the slot point only.

Fig. 218 shows the slot points at Bournemouth, which are very similar in their details to the London C. C., the principal difference perhaps being that there is a moveable track point on one side only. As will be seen in the cross section, this simplifies the mechanism required for connecting the tongues together.

A and B, fig. 219, show respectively a plan and side elevation of the fixed tongue between the two slots.

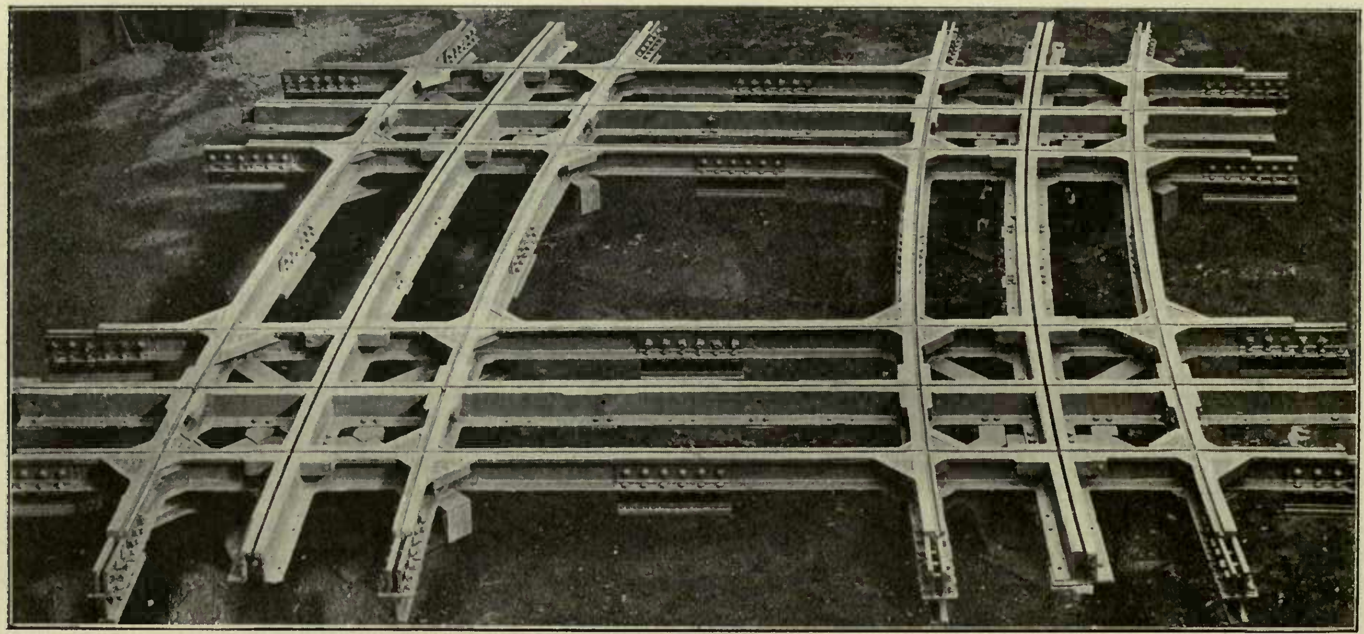


Fig. 222. Cast Steel Crossings for London County Council Tramways, made by Hadfield's.

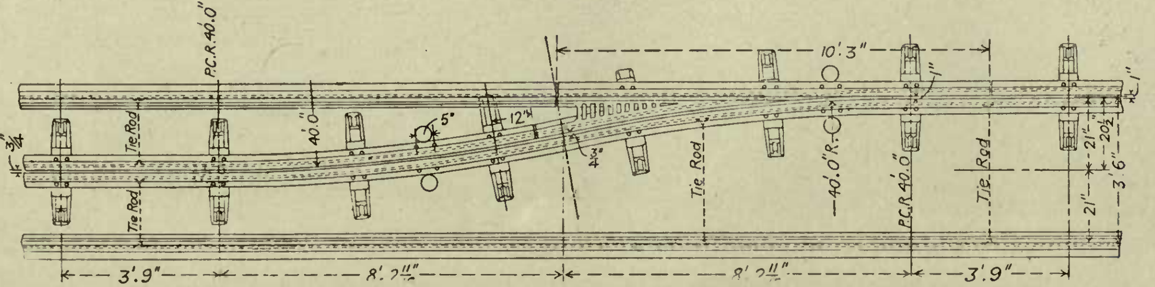


Fig. 223. Transition from Side to Cen're Slot, Bournemouth Corporation Tramways.

At C and D, fig. 219, are shown respectively plan and elevation of the castings on the outer parts of these slots. In the centre part of each is a recess forming a pocket for the reception of one of the moveable slot tongues, which are shown in detail at E and F, fig. 219. The recess is 2¾ ins. deep. The moveable tongues are ⅞ in. deep, and are covered by deeply checkered cast iron lids 1½ ins. thick, flush with the street surface, and forming the outer edge of the slot, shown separately at G, fig. 219.

The general arrangement of these parts will perhaps be more clearly understood by figs. 220 and 221, which are photographic reproductions of a set of points and crossings assembled together at the maker's works.

The former photo shows the slot tongues and part of the operating mechanism of one of the London C. C. points with all the covering lids removed. It will be seen here that the slot tongues have each a peculiar tooth shaped series of projections on their inner side in front of the tip of the fixed tongue. These fit into a corresponding set of recesses formed near the edge on the under-side of the covering lids, so that when these lids are placed in position, one or the other series of projections on the moveable tongues is thrown out and partially closes the slot so as to admit of a clear opening sufficient only for the passage of the current collecting shank. This is an improvement recently introduced by Messrs. Hadfield, and is not shown on the working drawings previously described. The other photograph shows the same set of points with the cover lids in position, it being understood that, with the exception of those over the moveable tongues, these lids have to be filled in with granite setts or wood blocks, according to the nature of the pavement in the roadway.

Mention may here be made of the crossings shown in the upper part of this fig. 221, and which will give some idea as to the complicated nature of the castings required. Another set of somewhat similar castings, also made by Hadfield's Steel Foundry Co., Ltd., Sheffield, is shown in fig. 222. The position of the joints can be clearly seen, and from them the nature of the difficulties may be inferred which have to be contended with in pattern making, moulding, and casting such difficult pieces of work.

At Bournemouth the distinctive feature of the tramways is the side slot, introduced, amongst other reasons, for the purpose of avoiding the troubles incidental to the use of a slot point which has to contend with the wear and tear due to heavy electric car traffic. Fig. 223 shows a plan of the track where the slot is diverted from the side to the centre in approaching a junction. The point thereby introduced is a point for the running track only—the slot itself with the tube underneath following the diverted line only, there is therefore no moveable parts or mechanism required in such a position.

* * *

NOTE A.

The Lemniscata.

This curve appears to be but little known; so far as the Author knows it is not dealt with in a comprehensive way in any book dealing with engineering topics, and as it undoubtedly meets the requirements of a transition curve in the most scientific way, it seems desirable to give some further particulars of its geometrical properties, and some plain directions for constructing it.

The curve is as easy to trace on as any can be in which a number of points have to be found to fix its position. Referred to rectangular co-ordinates, its equation is cumbersome to work out, but its polar equivalent is easily dealt with. The equation is generally given as a cosine formula, but there are certain advantages in using the sine formula. In the first place the "prime vector" at the origin is a tangent to the curve, and above all it is less trouble to deal with sines than with cosines on a slide rule.

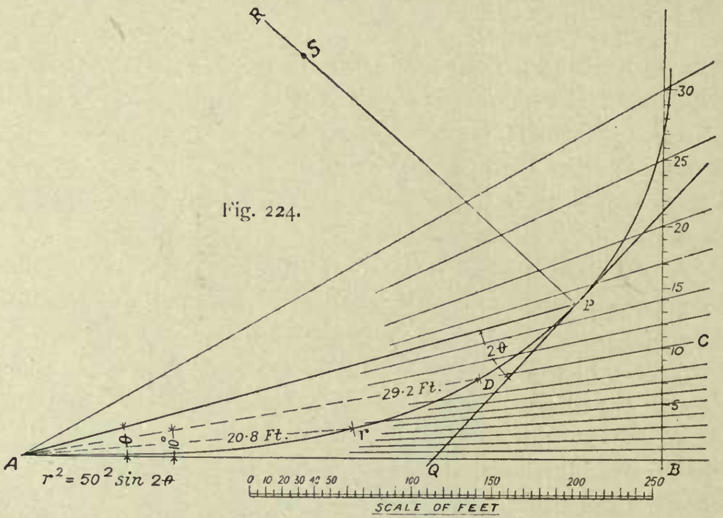


Fig. 224.

In constructing the curve as in fig. 224 let the tangent A B be taken as a base line, the curve commencing at the point A. The first step is to lay off, or to indicate in some way, the position of the radial lines which define the varying angle θ. They must be as close together as is deemed necessary to fix the curve, and this will depend upon the scale upon which it is drawn. The use of a protractor for setting out these radials needs no description, but in the absence of such an instrument, the lines can be quite as readily fixed by making A B = 10 ins., erecting a perpendicular at B, and setting off along it, in decimals of an inch, the successive values of natural tangents taken out of a table, and which is to be found in Molesworth's and most other books of engineering data. Or otherwise, the scale of tangents on a slide rule may be used, but it is easier to read the numbers out of a table than to shift the slide for every fresh angle.

The next step is to lay off along each of these radials, the value of r corresponding to that particular value of the angle θ, as calculated from the primary equation, *e.g.*, in fig. 78, along A C, making the angle $\theta = 10°$ with A B lay off the length

$$\text{A D} = r = \sqrt{(50^2 \text{ sin. } 20°)}$$

assuming 50 as the value for a. Sin. 20° according to the tables = ·342, so

$$r = \sqrt{(2{,}500 \times \cdot 342)} = 29\cdot 2.$$

With a slide rule* this little sum is worked out instantly, thus :—

Call the scales on the surface A, B, C, D. Pull the slide out until the sine of $2\ \theta = 20°$ is opposite the index mark at the back. This brings the value of sin. 20° = ·342 on B opposite to 1 on A, and opposite 50 on D is 29·2 on C, the value of $\sqrt{(50^2 \times \cdot 342)}$, or of r for this particular value of θ and a.

The sketch, fig. 225, may perhaps make this a little clearer. The sine of 20° is put in a circle to indicate that it has to be read on the back of the slide. This setting to the angle at the back is the only movement of the slide that is required

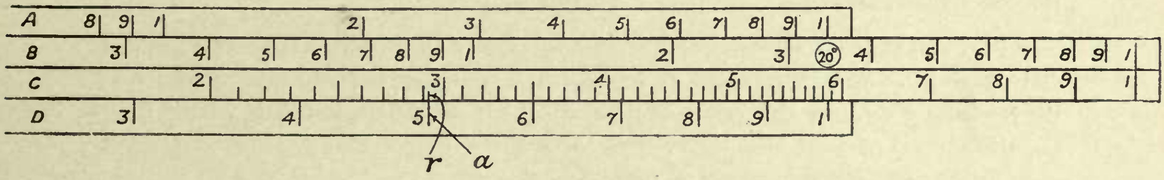


Fig. 225.

to ascertain the value of the radius vector : $2\ \theta°$ is set to the index mark at the back, and against the value of a on D is the corresponding value of r, or of the square root of a^2 sin. $2\ \theta$ on C.

The complete curve (or rather the half of it) is a pear-shaped figure, starting from A, curving round, and returning again to A in a direction at right angles to its commencement. The curvature varies from point to point, but its radius is always given by the equation

$$\rho = \frac{a^2}{3\ r}$$

This shows that the radius becomes infinite at the origin, no matter how small a may be, since r ultimately vanishes. If we substitute for r its value $a\ \sqrt{\text{sin}}$-

---

*The slide rule must be properly divided or it is of no use. Such rules are easily got, and they must not be confounded with the implement constructed of brass and boxwood, and sold as a "calculating slide rule" by unscrupulous ironmongers. The facility with which this cheap "near enough" divided imitation can be sold has done much to retard the use of the genuine article.

$2\ \theta$ in this equation we have

$$\rho = \frac{a}{3\sqrt{\sin.\ 2\ \theta}}.$$

The minimum value of the radius of curvature for any value of a, will then obviously be when sin. $2\ \theta$ is a maximum. This is when $2\ \theta = 90^\circ$, or $\theta = 45^\circ$, so that sin. $2\ \theta = 1$; the radius then becomes

$$\rho = \frac{a}{3}$$

and no matter how small the curve may be, its radius of curvature varies from this value to infinity. The position of the point having any specified radius of curvature in any curve, is found by transposing r and p in the above equation; thus

$$r = \frac{a^2}{3\ \rho}$$

In fig. 224, for example, the position of the point T, where the curvature is of 40 feet radius, is given by

$$r = \frac{50^2}{3 \times 40} = 20{\cdot}8 \text{ feet}$$

In applying the curve, it may be necessary to determine its tangent, and the position of the centre of curvature at any point. In fig. 224 let P be the point on the curve, and P A the corresponding radius vector, making the angle θ with A B. At P make the angle A P Q = $2\ \theta$, then the line P Q is a tangent to the curve at P. But it must also be tangent to the circle of curvature at that point; draw P R therefore perpendicular to P Q, and on this line make

$$\text{P S} = \frac{a^2}{3\ \text{P A}}$$

then S is the centre of the circle of curvation at P.

Fig. 226 shows a series of curves from $a = 20$ to $a = 100$. It will be noticed that when $\theta = 30^\circ$, the tangent is vertical; the centre of curvature is therefore in the horizontal through this point, and since $\sqrt{\sin.\ 60}$ differs but little from $\sqrt{\sin.\ 90}$, the central parts of the curve, lying between $\theta = 30^\circ$ and $\theta = 60^\circ$ differ but very little from an arc of circle of radius $= \frac{1}{3}\ a$.

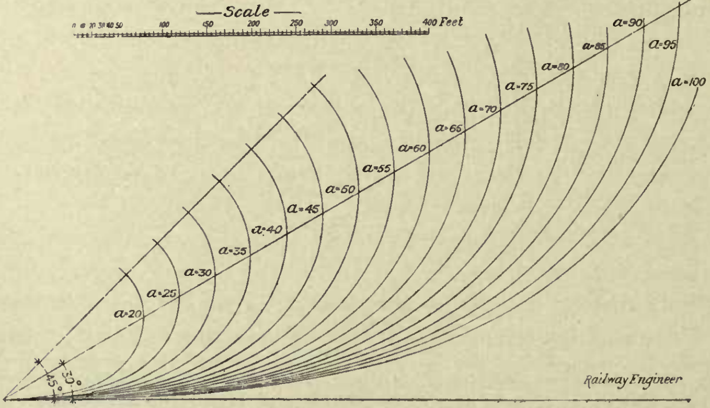


Fig. 226,

A practical difficulty in plotting the curve near the origin, owing to the very small angle made by the radius vector, may be avoided by taking advantage of the fact that here the curve differs insensibly from a cubic parabola. This is clear, because when 2θ is very small the sine and tangent both tend to equality with the arc and r becomes equal to x. Hence in the curve $r^2 = a^2 \sin. 2\theta$, we have for small values of 2θ, say less than two or three degrees, the equation may take the form

$$x^2 = a^2 \frac{2y}{x}; \text{ and } y = \frac{x^3}{2a^2}$$

from which this part of the curve will be more easily plotted than from the polar equation. Of course for large values of 2θ the discrepancy between the two curves cannot be neglected.

This curve must not be confounded with the "lemniscata" given in Molesworth's book. There is perhaps not much in the name; it appears to be rather loosely applied to a series of curves, which, when plotted with all possible values of the variables, take the form of a series of loops arranged round the centre of a circle. There is, however, a very substantial difference in the shape of the curves. The one that has been dealt with in this paper has for its ordinary equation

$$(x^2+y^2)^2 = a^2(x^2-y^2)$$

which is more neatly expressed in its polar form

$$r^2 = a^2 \sin 2\theta$$
$$\text{or } r^2 = a^2 \cos 2\theta$$

Both of these equations give the same curve, one being merely shifted 45° round in its position on the paper. The Author prefers the sine formula for reasons already given. The equation to Molesworth's lemniscata is,

$$y = \frac{x\sqrt{(a^2-x^2)}}{a}; \text{ or}$$
$$a^2 y^2 = x^2(a^2-x^2)$$

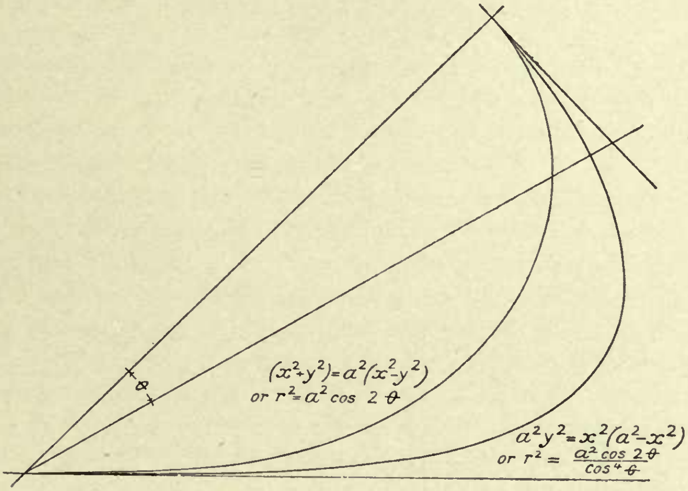

θ
$(x^2+y^2)=a^2(x^2-y^2)$
or $r^2=a^2 \cos 2\theta$
$a^2y^2=x^2(a^2-x^2)$
or $r^2 = \frac{a^2 \cos 2\theta}{\cos^4\theta}$

Fig. 227.

When transformed to polar co-ordinates, this becomes

$$r^2 = \frac{a^2 \cos 2\theta}{\cos^4 \theta}$$

which curiously resembles the equation to the other curve. As the value of a cosine is (except in the limit) always less than 1, the introduction of the fourth power of a cosine as a divisor will have the effect of lengthening r beyond what its value would be at the corresponding value of θ in the other formula.

Its influence on the form of the curve is shown in fig. 227, where both curves are drawn with the same value of the constant a. Molesworth's curve is much flatter near the origin; its curvature then rapidly increases, reaching a maximum with a minimum radius of $\frac{a}{4}$ at about $\theta = 30°$, flattening again to a radius $=a$ as it crosses the prime vector. It has many interesting properties, but is not suitable for the work under discussion, inasmuch as it does not possess the essential property of having a curvature varying directly as the distance from the tangent point.

* * *

NOTE B.

As to Rail Corrugations.

The extended use of electric traction, and consequent increased speed of the cars during the last two or three years, has brought into prominence a peculiar effect of wear and tear upon the rails. The top surface is worn into "waves" or corrugations; the length of the "waves" or pitch of the corrugations is generally from 2 ins. to 3 ins. Sometimes it may be as short as 1½ ins., but it is very seldom over 3 ins. The length probably varies according to the average speed. A great noise is caused by running cars over such corrugated rails, and it appears certain that in order to mitigate the nuisance so caused great expense will have to be incurred on many tramways in changing the metals before they would otherwise be deemed "worn out."

Uniformity in the rolling stock, and a fairly high average speed appear to give favourable conditions for the development of this defect. On that section of the Birmingham Cable Tramways outside the city it has been a great cause of trouble and expense for a number of years : inside the city, it has never appeared. The tracks are identical in structure throughout, and the car service is also identical : the *only* difference is that inside the city the speed limit is 7 miles an hour, whereas at the city boundary the cars engage with another cable and the speed is increased to about 9 miles. There is a peculiar vibration set up at the higher speed which does not exist at the lower one.

As to the corrugations themselves, it is at once noticed that on curved sections of the road they occur only on the outside rail of the curve; on curves of very large radius there are, however, a few very faint indications on the inside rail also. It is probable that the centrifugal force due to the curve increases the load on the outer wheels so that all the slip has to take place on the inside rail, and the waves are ground away as fast as they are formed. On straight tracks the waves appear indifferently on one rail or the other, but seldom on both : when both rails are affected, one is much worse than the other. On this tramway the rails are bolted down to tube-yokes embedded in the concrete at 4 ft. intervals, and the influence of these points of constraint can generally be seen by the varying strength of the corrugations on the surface. Although these remarks relate to a cable tramway, the same general description of the phenomena applies equally to the defect when developed on an electric tramway.

The trouble is due to a torsional vibration of the car axles, or of the wheels and axle taken as a whole. Consider the case of a curved track : the outer wheel on any given axle has to roll a distance equal to its own circumference in making one revolution. The inner wheel has a shorter distance to go in the same time and it therefore acts as a drag upon the other one, bending the spokes (if any) and twisting the axle. They cannot go far before the spring is released and the wheels and axles fly back to equilibrium again, when the process is repeated.

At the moment of the release both wheels suffer an equal shock at their bearing points on the rail, but in opposite directions. The wheel carrying the greatest pressure cannot slip, and the result is a deformation of the surface : under the other wheel, the slip grinds away the deformation as fast as it develops. It is probable that there would be less trouble from this cause, on curves at least, if the car axle had some degree of radial freedom.

The remedy for this trouble must be found by the builders of the rolling stock. As at present the wheels are liable to set up a vibration with a period of 80 per second or thereabouts, the pulses hammering the rails into the wavy shape referred to. The period is far too short to be accounted for by any bouncing of the car upon its springs, and the fact that, in general, one rail only is affected is sufficient to show that the cause cannot be found in a movement of this kind. A *torsional* vibration is, however, quite another matter : it must *tend* to set up whenever one wheel has greater friction to overcome than the other—whenever one wheel acts as a drag upon the other. The mechanical features of the problem are not of a very difficult character, but they do not appertain to the permanent way.

◆

APPENDIX I.

THE TRAMWAYS ACT, 1870.

[33 & 34 Vict. 78 Chap. 9th August, 1870.]

Extracts referring more particularly to permanent way.

Preliminary.

1. This Act may be cited for all purposes as "The Tramways Act, 1870." **Short title.**

2. This Act shall not extend to Ireland. **Limitation.**

3. Interpretation clause: *inter alia.*

The term "road" shall mean any carriageway being a public highway and the carriageway of any bridge forming part of or leading to the same:

4.
5.
6.
7.
} As to applications, and powers of Board of Trade to make Provisional Orders.

Power for Board of Trade to make Provisional Order.

8. Where it appears to the Board of Trade expedient and proper that the application should be granted, with or without addition or modification, or subject or not to any restriction or condition, the Board of Trade may settle and make a Provisional Order accordingly.

Form and contents of Provisional Order.

Every such Provisional Order shall empower the promoters therein specified to make the tramway upon the gauge and in manner therein described, and shall contain such provisions as (subject to the requirements of this Act) the Board of Trade, according to the nature of the application and the facts and circumstances of each case, think fit to submit to Parliament for confirmation in manner provided by this Act; but so that any such Provisional Order shall not contain any provision for empowering the promoters or any other person to acquire lands otherwise than by agreement, or to acquire any lands, even by agreement, except to an extent therein limited, or to construct a tramway elsewhere than along or across a road, or upon land taken by agreement.

Regulations as to construction of tramways in towns.

9. Every tramway in a town which is hereafter authorised by Provisional Order shall be constructed and maintained as nearly as may be in the middle of the road; and no tramway shall be authorised by any Provisional Order to be so laid that for a distance of thirty feet or upwards a less space than nine feet and six inches shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway if one third of the owners or one third of the occupiers of the houses, shops, or warehouses abutting upon the part of the road where such less space shall intervene as aforesaid shall in the prescribed manner and at the prescribed time express their dissent from any tramway being so laid.

10.
11.
12.
13.
14.
15.
16.
17.
} As to details of procedure, incorporation of General Acts, and powers of Board of Trade to amend Orders, or authorise joint work.

Cesser of powers at expiration of prescribed time.

18. If the promoters, empowered by any Provisional Order under this Act to make a tramway, do not, within two years from the date of the same, or within any shorter period prescribed therein, complete the tramway and open it for public traffic; or,

If within one year from the date of the Provisional Order, or within such shorter time as is prescribed in the same, the works are not substantially commenced; or,

If the works having been commenced are suspended without a reason sufficient in the opinion of the Board of Trade to warrant such suspension;

the powers given by the Provisional Order to the promoters for constructing such tramway, executing such works, or otherwise in relation thereto, shall cease to be exercised, except as to so much of the same as is then completed, unless the time be prolonged by the special direction of the Board of Trade; and as to so much of the same as is then completed the Board of Trade may allow the said powers to continue and to be exercised if they shall think fit, but failing such permission the same shall cease to be exercised, and where such permission is withheld then so much of the said tramway as is then completed shall be deemed to be a tramway to which all the provisions of this Act relating to the discontinuance of tramways after proof of such discontinuance shall apply, and may be dealt with accordingly.

A notice purporting to be published by the Board of Trade in the London or Edinburgh Gazette, accordingly as the district to which it relates is situate in England or Scotland, to the effect that a tramway has not been completed and opened for public traffic, or that the works have not been substantially commenced, or that they have been suspended without sufficient reason, shall be conclusive evidence for the purposes of this section of such non-completion, non-commencement, or suspension.

19.
20. } As to leases and defraying expenses.
21.

PART II.

Construction of Tramways

As to incorporation of Parts II. and III. of this Act with Provisional Order and Special Acts.

22. Part II. and Part III. of this Act shall apply to every tramway which is hereafter authorised by any Provisional Order or Act of Parliament, and shall be incorporated with such Provisional Order or Act, and all the said provisions of this Act, save so far as they shall be expressly varied or excepted by any such Provisional Order or Act, shall apply to the undertaking authorised thereby, so far as the same shall be applicable to such undertaking, and shall, with the provisions of every other Act or part of any Act which shall be incorporated therewith, form part of the said Provisional Order or Act, and be construed therewith as forming one Provisional Order or Act, as the case may be.

"Special Act."

23. In Part II. and Part III. of this Act, the term "special Act" shall be construed to mean any Act of Parliament which shall be hereafter passed or any Provisional Order authorising the construction of a tramway, and with which the said parts of this Act shall be incorporated as aforesaid.

"Promoters."

24. The term "the promoters" shall mean any person, persons, corporation, company, or local authority authorised by special Act to construct a tramway.

Mode of formation of tramways.

25. Every tramway which is hereafter authorised by special Act shall be constructed on such gauge as may be prescribed by such special Act, and if no gauge is thereby prescribed, on such gauge as will admit of the use upon such tramways of carriages constructed for use upon railways of a gauge of four feet eight inches and half an inch, and shall be laid and maintained in such manner that the uppermost surface of the rail shall be on a level with the surface of the road, and shall not be opened for public traffic until the same has been inspected and certified to be fit for such traffic, in the prescribed manner.

Power to break up streets, &c.

26. The promoters from time to time, for the purpose of making, forming, laying down, maintaining, and renewing any tramway duly authorised, or any part or parts thereof respectively, may open and break up any road, subject to the following regulations:

1. They shall give to the road authority notice of their intention, specifying the time at which they will begin to do so, and the portion of road proposed to be opened or broken up, such notice to be given seven days at least before the commencement of the work:
2. They shall not open, or break up, or alter the level of any road, except under the superintendence and to the reasonable satisfaction of the road authority, unless that authority refuses or neglects to give such superintendence at the time specified in the notice, or discontinues the same during the work:
3. They shall pay all reasonable expenses to which the road authority is put on account of such superintendence:
4. They shall not, without the consent of the road authority, open or break up at any one time a greater length than one hundred yards of any road which does not exceed a quarter of a mile in length, and in the case of any road exceeding a quarter of a mile in length the promoters shall leave an interval of at least a quarter of a mile between any two places at which they may open or break up the road, and they shall not open or break up at any such place a greater length than one hundred yards.

Where the carriageway over any bridge forms part of or is a road within the jurisdiction of a road authority, but such bridge is vested in some person or persons, corporation, or company, distinct from such road authority, any work which the promoters may be empowered to construct, and which affects or in anywise interferes with the structural works of such bridge, shall be constructed under the superintendence (at the cost of the promoters) and to the reasonable satisfaction of such person, persons, corporation, or company, unless after notice to be given by the promoters seven days at least before the commencement of such work such superintendence is refused or withheld.

Where the carriageway in or upon which any tramway is proposed to be formed or laid down is crossed by any railway or tramway on the level, any work which the promoters may be empowered to construct, and which affects or in anywise interferes with such railway or tramway, or the traffic thereon, shall be constructed and maintained under the superintendence (at the cost of the promoters) and to the reasonable satisfaction of the person, corporation, or company owning such railway or tramway, unless after notice to be given by the promoters seven days at least before the commencement of such work such superintendence is refused or withheld.

Completion of work and reinstatement of road.

27. When the promoters have opened or broken up any portion of any road, they shall be under the following further obligations; namely,

1. They shall, with all convenient speed, and in all cases within four weeks at the most (unless the road authority otherwise consents in writing) complete the work on account of which they opened or broke up the same, and (subject to the formation, maintenance, or renewal of the tramway) fill in the ground and make good the surface, and, to the satisfaction of the road authority, restore the portion of the road to as good condition as that in which it was before it was opened or broken up, and clear away all surplus paving or metalling material or rubbish occasioned thereby:
2. They shall in the meantime cause the place where the road is opened or broken up to be fenced and watched, and to be properly lighted at night:
3. They shall bear or pay all reasonable expenses of the repair of the road for six months after the same is restored, as far as those expenses are increased by the opening or breaking up.

If the promoters aforesaid fail to comply in any respect with the provisions of the present section, they shall for every such offence (without prejudice to the enforcement of specific performance of the requirements of this Act or to any other remedy against them) be liable to a penalty not exceeding twenty pounds, and to a further penalty not exceeding five pounds for each day during which any such failure continues after the first day on which such penalty is incurred.

Repair of part of road where tramway is laid.

28. The promoters shall, at their own expense, at all times maintain and keep in good condition and repair, with such materials and in such manner as the road authority shall direct, and to their satisfaction, so much of any road whereon any tramway belonging to them is laid as lies between the rails of the tramway and (where two tramways are laid by the same promoters in any road at a distance of not more than four feet from each other) the portion of the road between the tramways, and in every case so much of the road as extends eighteen inches beyond the rails of and on each side of any such tramway. If the promoters abandon their undertaking, or any part of the same, and take up any tramway or any part of any tramway belonging to them, they shall with all convenient speed, and in all cases within six weeks at the most (unless the road authority otherwise consents in writing), fill in the ground and make good the surface, and, to the satisfaction of the road authority, restore the portion of the road upon which such tramway was laid to as good a condition as that in which it was before such tramway was laid thereon, and clear away all surplus paving or metalling material or rubbish occasioned by such work; and they shall in the meantime cause the place where the road is opened or broken up to be fenced and watched, and to be properly lighted at night: Provided always, that if the promoters fail to comply with the provisions of this section, the road authority, if they think fit, may themselves at any time, after seven days notice to the promoters, open and break up the road, and do the works necessary for the repair and maintenance or restoration of the road, to the extent in this section above mentioned, and the expense incurred by the road authority in so doing shall be repaid to them by the promoters.

Road authority and promoters may contract for paving roads on which tramways are laid.

29. The road authority on the one hand and the promoters on the other hand may from time to time enter into and carry into effect, and from time to time alter, renew, or vary, contracts, agreements, or arrangements with respect to the paving and keeping in repair of the whole or any portion of any road on which the promoters shall lay any tramway, and the proportion to be paid by either of them of the expense of such paving and keeping in repair.

Provision as to gas and water companies.

30. For the purpose of making, forming, laying down, maintaining, repairing, or renewing any of their tramways, the promoters may from time to time, where and as far as it is necessary, or may appear expedient for the purpose of preventing frequent interruption of the traffic by repairs or works in connexion with the same, alter the position of any mains or pipes for the supply of gas or water, or any tube, wires, or apparatus for telegraphic or other purposes, subject to the provisions of this Act, and also subject to the following restrictions; (that is to say,)

1. Before laying down a tramway in a road in which any mains or pipes, tubes, wires, or apparatus may be laid, the promoters shall, whether they contemplate altering the position of any such mains or pipes, wires, or apparatus, or not, give seven days notice to the company, persons, or person to whom such mains or pipes, tubes, wires, or apparatus may belong or by whom they are controlled, of their intention to lay down or alter the tramway, and shall at the same time deliver a plan and section of the proposed work. If it should appear to any such company or persons that the construction of the tramway as proposed would endanger any such main or pipe, tube, wire, or apparatus, or interfere with or impede the supply of water or gas or the telegraphic or other communication, such company or person (as the case may be) may give notice to the promoters to lower or otherwise alter the position of the said mains or pipes, tubes, wires, or apparatus in such manner as may be considered necessary, and any difference as to the necessity of any such lowering or alteration shall be settled in manner provided by this Act for the settlement of differences between the promoters and other companies or persons, and all alterations to be made under this section shall be made with as little detriment and incon-

venience to the company or person to whom such mains or pipes, tubes, wires, or apparatus may belong, or by whom the same are controlled, or to the inhabitants of the district, as the circumstances will admit, and under the superintendence of such company or person or of their surveyor or engineer if they or he think fit to attend, after receiving not less than forty-eight hours notice for that purpose, which notice the promoters are hereby required to give:

2. The promoters shall not remove or displace any of the mains or pipes, valves, syphons, plugs, tubes, wires, or apparatus, or other works belonging to or controlled by any such company or person, or do anything to impede the passage of water or gas or the telegraphic or other communication into or through such mains or pipes, without the consent of such company or person, or in any other manner than such company or person shall approve, until good and sufficient mains, pipes, valves, syphons, plugs, and other works necessary or proper for continuing the supply of water or gas or telegraphic or other communication, as sufficiently as the same was supplied by the mains or pipes, tubes, wires, or apparatus proposed to be removed or displaced, shall at the expense of the promoters have been first made and laid down in lieu thereof and ready for use, and to the satisfaction of the surveyor or engineer of such water or gas or other company, or of such person, or, in case of disagreement between such surveyor or engineer and the promoters, as an engineer appointed by the Board of Trade shall direct:
3. The promoters shall not lay down any such pipes contrary to the regulations of any Act of Parliament relating to such water or gas or other company, or relating to telegraphs:
4. The promoters shall make good all damage done by them to property belonging to or controlled by any such company or person, and shall make full compensation to all parties for any loss or damage which they may sustain by reason of any interference with such property, or with the private service pipes of any person supplied by any such company or person with water or gas:
5. If by any such operations as aforesaid the promoters interrupt the supply of water or gas in or through any main or main pipe they shall be liable to a penalty not exceeding twenty pounds for every day upon which such supply shall be so interrupted.

For protection of sewers, &c.

31. Where in any district any tramway or any work connected therewith interferes with any sewer, drain, watercourse, subway, defence, or work in such district, or in any way affects the sewerage or drainage of such district, the promoters shall not commence any tramway or work until they shall have given to the proper authority fourteen days previous notice in writing of their intention to commence the same, by leaving such notice at the principal office of such authority with all necessary particulars relating thereto, nor until such authority shall have signified their approval of the same, unless such authority do not signify their approval, disapproval, or other directions within fourteen days after service of the said notice and particulars as aforesaid, and the promoters shall comply with and conform to all reasonable directions and regulations of the said authority in the execution of the said works, and shall provide by new, altered, or substituted works, in such manner as such authority shall reasonably require, for the proper protection of and for preventing injury or impediment to the sewers and works hereinbefore referred to, by or by reason of the tramways, and shall save harmless the said authority against all and every the expense to be occasioned thereby; and all such works shall be done under the direction, superintendence, and control of the engineer or other officer or officers of the said authority, at the reasonable costs, charges and expenses in all respects of the promoters; and when any new, altered, or substituted work as aforesaid, or any works or defence connected therewith, shall be completed by or at the costs, charges, or expenses of the promoters, under the provisions of this Act, the same shall thereafter be as fully and completely under the direction, jurisdiction, and control of the said authority and be maintained by them as any sewers or works.

Rights of authorities and companies, &c. to open roads.

32. Nothing in this Act shall take away or abridge any power to open or break up any road along or across which any tramway is laid, or any other power vested in any local authority or road authority for any of the purposes for which such authority is respectively constituted, or in any company, body, or person for the purpose of laying down, repairing, altering, or removing any pipe for the supply of gas or water, or any tubes, wires, or apparatus for telegraphic or other purposes, but in the exercise of such power every such local authority, road authority, company, body, or person shall be subject to the following restrictions; (that is to say,)

1. They shall cause as little detriment or inconvenience to the promoters and lessees as circumstances admit:
2. Before they commence any work whereby the traffic on the tramway will be interrupted they shall (except in cases of urgency, in which cases no notice shall be necessary) give to the promoters and lessees, if there be any, notice of their intention to commence such work, specifying the time at which they will begin to do so, such notice to be given eighteen hours at least before the commencement of the work:
3. They shall not be liable to pay to the promoters or lessees any compensation for injury done to the tramway by the execution of such work, or for loss of traffic occasioned thereby, or for the reasonable exercise of the powers so vested in them as aforesaid:
4. Whenever for the purpose of enabling them to execute such work the local authority or the road authority shall so require, the promoters or lessees shall either stop traffic on the tramway to which such notice shall refer, where it would otherwise interfere with such work, or shore up and secure the same at their own risk and cost during

the execution of the work there: Provided that such work shall always be completed by the local authority or the road authority, as the case may be, with all reasonable expedition:

5. Any company, body, or person shall not execute such work so far as it immediately affects the tramway except under the superintendence of the promoters, unless they refuse or neglect to give such superintendence at the time specified in the notice for the commencement of the work or discontinue the same during the progress of the work; and they shall execute such work at their own expense, and to the reasonable satisfaction of the promoters: Provided that any additional expense imposed upon them by reason of the existence of the tramway in any road or place where any such mains, pipes, tubes, wires, or apparatus shall have been laid before the construction of such tramway shall be borne by the promoters.

Difference between promoters and road authority, &c.

33. If any difference arises between the promoters or lessees on the one hand and any local authority or road authority, or any gas or water company, or any company, body, or person to whom any sewer, drain, tube, wires, or apparatus for telegraphic or other purposes may belong, or any other company, on the other hand, with respect to any interference or control exercised, or claimed to be exercised, by them or him, or on their or his behalf, or by the promoters or lessees by virtue of this Act, in relation to any tramway or work, or in relation to any work or proceeding of the local authority, road authority, body, company, or person, or with respect to the propriety of or the mode of execution of any work relating to any tramway, or with respect to the amount of any compensation to be made by or to the promoters or lessees, or on the question whether any work is such as ought reasonably to satisfy the local authority, road authority, body, company, or person concerned, or with respect to any other subject or thing regulated by or comprised in this Act, the matter in difference shall (unless otherwise specially provided by this Act) be settled by an engineer or other fit person nominated as referee by the Board of Trade on the application of either party, and the expenses of the reference shall be borne and paid as the referee directs.

PART III.

General Provisions.

Carriages.

Power for promoters to use tramways with flange-wheeled carriages, &c.

34. The promoters of tramways authorised by special Act and their lessees may use on their tramways carriages with flange wheels or wheels suitable only to run on the rail prescribed by such Act; and, subject to the provisions of such special Act and of this Act, the promoters and their lessees shall have the exclusive use of their tramways for carriages with flange wheels or other wheels suitable only to run on the prescribed rail.

All carriages used on any tramway shall be moved by the power prescribed by the special Act, and where no such power is prescribed, by animal power only.

No carriage used on any tramway which is hereafter authorised by special Act shall extend beyond the outer edge of the wheels of such carriage more than eleven inches on each side.

35.
36.
37. } As to licenses, tolls, and liability of owners of cars for damages.
38.
39.
40.

Discontinuance of Tramways.

Tramways to be removed in certain cases.

41. If at any time after the opening of any tramway in any district for traffic the promoters discontinue the working of such tramway, or of any part thereof, for the space of three calendar months (such discontinuance not being occasioned by circumstances beyond the control of such promoters, for which purpose the want of sufficient funds shall not be considered a circumstance beyond their control), and such discontinuance is proved to the satisfaction of the Board of Trade, the said Board, if they think fit, may by order declare that the powers of the promoters in respect of such tramway or the part thereof so discontinued shall, from the date of such order, be at an end, and thereupon the said powers of the promoters shall cease and determine, unless the same are purchased by the local authority in manner by this Act provided. Where any such order has been made, the road authority of such district may at any time after the expiration of two months from the date of such order, under the authority of a certificate to that effect by the Board of Trade, remove the tramway or part of the tramway so discontinued, and the promoters shall pay to the road authority the cost of such removal and of the making good of the road by the road authority, such cost to be certified by the clerk for the time being, or by some other authorised officer of the road authority, whose certificate shall be final and conclusive; and if the promoters fail to pay the amount so certified within one calendar month after delivery to them of such certificate or a copy thereof, the road authority may, without any previous notice to the promoters (but without prejudice to any other remedy which they may have for the recovery of the amount), sell and dispose of the materials of the tramway or part of tramway removed, either by public auction or private sale, and for such sum or sums, and to such person or persons, as the road authority may think fit, and may out of the proceeds of such sale pay and reimburse themselves the amount of the cost certified as aforesaid and of the cost of sale, and the balance (if any) of the proceeds of the sale shall be paid over by the road authority to the promoters.

42. Proceedings in case of insolvency.

Purchase of Tramways.

Future purchase of undertaking by local authority.

43. Where the promoters of a tramway in any district are not the local authority, the local authority, if, by resolution passed at a special meeting of the members constituting such local authority they so decide, may within six months after the expiration of a period of twenty-one years from the time when such promoters were empowered to construct such tramway, and within six months after the expiration of every subsequent period of seven years, or within three months after any order made by the Board of Trade under either of the two next preceding sections, with the approval of the Board of Trade, by notice in writing require such promoters to sell, and thereupon such promoters shall sell to them their undertaking, or so much of the same as is within such district, upon terms of paying the then value (exclusive of any allowance for past or future profits of the undertaking, or any compensation for compulsory sale, or other consideration whatsoever) of the tramway, and all lands, buildings, works, materials, and plant of the promoters suitable to and used by them for the purposes of their undertaking within such district, such value to be in case of difference determined by an engineer or other fit person nominated as referee by the Board of Trade on the application of either party, and the expenses of the reference to be borne and paid as the referee directs. And when any such sale has been made, all the rights, powers, and authorities of such promoters in respect to the undertaking sold, or where any order has been made by the Board of Trade under either of the next preceding sections, all the rights, powers, and authorities of such promoters previous to the making of such order in respect to the undertaking sold, shall be transferred to, vested in, and may be exercised by the authority to whom the same has been sold, in like manner as if such tramway was constructed by such authority under the powers conferred upon them by a Provisional Order under this Act, and in reference to the same they shall be deemed to be the promoters.

No such resolution shall be valid unless a month's previous notice of the meeting, and of the purpose thereof, has been given in manner in which notices of meetings of such local authority are usually given, nor unless two thirds of the members constituting such local authority are present and vote at the meeting and a majority of those present and voting concur in the resolution; provided that if in Scotland the local authority be the road trustees it shall not be necessary that two-thirds of such trustees shall be present at the meeting but the resolution shall not be valid unless two thirds of the members present vote in favour of such resolution, and unless the said resolution is confirmed in like manner at another meeting called as aforesaid and held not less than three weeks and not more than six weeks thereafter; and it shall be lawful for the chairman of any such meeting, with the consent of a majority of the members present, to adjourn the same from time to time.

The local authority in any district may pay the purchase money and all expenses incurred by them in the purchase of any undertaking under the authority of this section out of the like rate, and shall have the like powers to borrow on the security of the same as if such expenses were incurred in applying for, obtaining, and carrying into effect any Provisional Order obtained by them under this Act.

Where the local rate is limited by law to a certain amount, and is by reason of such limitation insufficient for the payment of such purchase money and expenses, the Board of Trade may by Provisional Order extend the limit of such local rate to such amount as they shall think fit and prescribe for the payment of such purchase money and expenses.

Every such Provisional Order shall be confirmed in like manner as a Provisional Order under the authority of Part I. of this Act, and until such confirmation such Provisional Order shall not have any operation.

Subject and according to the preceding provisions of this section two or more local authorities may jointly purchase any undertaking or so much of the same as is within their districts.

44. Power of sale.

45. Tolls to be specified in special Act.

46.
47. As to bye-laws.
48.

Offences.

Penalty for obstruction of promoters in laying out tramway.

49. If any person wilfully obstructs any person acting under the authority of any promoters in the lawful exercise of their powers in setting out or making, forming, laying down, repairing, or renewing a tramway, or defaces or destroys any mark made for the purpose of setting out the line of the tramway, or damages or destroys any property of any promoters, lessees, or licensees, he shall for every such offence be liable to a penalty not exceeding five pounds.

Penalties for wilful injury or obstruction to tramways, &c.

50. If any person, without lawful excuse (the proof whereof shall lie on him), wilfully does any of the following things; (namely,)

Interferes with, removes, or alters any part of a tramway or of the works connected therewith;

Places or throws any stones, dirt, wood, refuse, or other material on any part of a tramway;

Does or causes to be done any thing in such manner as to obstruct any carriage using a tramway, or to endanger the lives of persons therein or thereon;

Or knowingly aids or assists in the doing of any such thing;

he shall for every such offence be liable (in addition to any proceedings by way of indictment or otherwise to which he may be subject) to a penalty not exceeding five pounds.

51. 52. 53. 54. Penalties in case of fraud, bringing dangerous goods, and unauthorised parties using carriages with flanged wheels.
55. Responsibility for damages.
56. Recovery of tolls.
57. Right of user.
58. Turnpike Trustees.
59. Mine owners' rights.

60. Nothing in this Act shall take away or affect any power which any road authority, or the owners, commissioners, undertakers, or lessees of any railway, tramway, or inland navigation, may have by law to widen, alter, divert, or improve any road, railway, tramway, or inland navigation.

Reserving powers of street authorities to widen, &c. roads.

61. 62. 63. 64. As to regulating traffic. Enquiries by Board of Trade, and Rules for carrying Act into effect.

The Schedules to the Act describe the Local Authorities and state how their approval to an Order shall be given. Regulations are also given as to Advertisements and Deposits at various stages of the Parliamentary work, &c.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA

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APPENDIX II.

BOARD OF TRADE RULES UNDER THE TRAMWAYS ACT, 1870.

Extracts* referring more particularly to Permanent Way.

Advertisement as to narrow places.

Rule IV.—The advertisement must specify at what point or points, and on which side of the street or road, it is proposed to lay such tramway, so that for a distance of thirty feet or upwards a less space than nine feet six inches, or if it is intended to run thereon carriages or trucks adapted for use upon railways, a less space than ten feet six inches shall intervene between the outside of the footpath on the side of the street or road and the nearest rail of the tramway. The notice shall also specify the gauge to be adopted, and what power it is intended to employ for moving carriages or trucks upon the tramway.

Street notice.

Rule V.—In the months of October and November, or one of them, immediately preceding the application for any Provisional Order, a notice thereof shall be posted for fourteen consecutive days in every street or road, along which it is proposed to lay the tramway in such manner as the authority having the control of such street or road shall direct; and if after application to such authority no such direction shall be given, then in some conspicuous position in such street or road; and such notice shall also state the place or places at which the plans of such tramway will be deposited.

Notice to owners and lessees of tramways, railways, and canals.

Rule VI.—On or before the 15th day of December immediately preceding the application for any Provisional Order for laying down a tramway crossing any railway or tramway on the level, or crossing any railway, tramway, or canal by means of a bridge, or otherwise affecting or interfering with such railway, tramway, or canal, notice in writing of such application shall be served upon the owner or reputed owner and upon the lessee or reputed lessee of such railway, tramway, or canal, and such notice shall state the place or places at which the plans of the tramway to be authorised by such Provisional Order have been or will be deposited.

Similar notice must also be given to county councils and to proprietors of navigable rivers in respect of their bridges or other works which are proposed to be crossed or otherwise interfered with.

Every notice under this Rule must be accompanied by a copy of Rule XVII., omitting the first paragraph, and must state where copies of the draft Provisional Order, when deposited at the Board of Trade, can be obtained.

Notice to local and road authorities

Rule VII.—Where the promoters make application for an extension of time for the construction of, or for authority to abandon, any tramway, they must, on or before the 15th day of December, serve notice of such application upon all the local and road authorities affected.

Intimation to intending objectors.

Rule VIII.—The preceding advertisement and notices, other than the street notice, must state that every company, corporation, or person desirous of making any representation to the Board of Trade, or of bringing before them any objection respecting the application, may do so by letter, addressed to the Assistant Secretary of the Railway Department of the Board of Trade, *on or before the 15th January* next ensuing; that copies of their objections must at the same time be sent to the promoters; and that in forwarding to the Board of Trade such objections, the objectors or their agents should state that a copy of the same has been sent to the promoters or their agents.

Notice to frontagers.

Rule IX.—On or before the 15th day of December immediately preceding the application for a Provisional Order, notice in writing must be given to the owners or reputed owners, lessees or reputed lessees, and occupiers of all houses, shops, or warehouses abutting upon any part of any street or road where, for a distance of thirty feet or upwards, it is proposed that a less space than nine feet six inches shall intervene between the outside of the footpath on either side of the road and the nearest rail of the tramway.

This notice should be given in respect of such premises on both sides of the road, and must contain a notification that if such owner, lessee, or occupier dissents from the tramway being so laid, he may express his dissent by a statement in writing, addressed to the Assistant Secretary of the Railway Department of the Board of Trade, *on or before the 1st January* next ensuing, and that he must at the same time send a copy of his dissent to the promoters.

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*The full text of these rules may be obtained through any bookseller; published price fourpence.

Requirements as to plans.

RULE XI.—The plans to be deposited must also comply with the following requirements:—

The plans shall indicate whether it is proposed to lay the tramway along the centre of any street or road, and if not along the centre, then on which side of, and at what distance from, an imaginary line drawn along the centre of such street or road, and whether or not, and if so, at what point or points, it is proposed to lay such tramway, so that for a distance of thirty feet or upwards a less space than nine feet six inches, or if it is intended to run thereon carriages or trucks adapted for use upon railways, a less space than ten feet six inches, shall intervene between the outside of the footpath on either side of the street or road and the nearest rail of the tramway.

All lengths shall be stated on the plan and section in miles, furlongs, chains, and decimals of a chain.

The distances in miles and furlongs from one of the termini of each tramway shall be marked on the plan and section.

Each double portion of tramway, whether a passing-place or otherwise, shall be indicated by a double line.

The total length of the street or road upon which each tramway is to be laid shall be stated (*i.e.*, the length of route of each tramway).

The length of each double and single portion of such tramway, and the total length of such double and single portions respectively, shall also be stated.

In the case of double lines (including passing-places), the distance between the centre lines of each line of tramway shall be marked on the plans. This distance must in all cases be sufficient to leave at least 15 inches between the sides of the widest carriage and engines to be used on the tramways when passing one another.

The gradients of the street or road on which each tramway is to be laid shall be marked on the section.

Every crossing of a railway, tramway, river, or canal shall be shown, specifying in the case of railways and tramways whether they are crossed over, under, or on the level.

All tidal waters shall be coloured blue.

All places, where for a distance of 30 feet and upwards there will be a less space than nine feet six inches between the outside of the footpath on either side of the street or road and the nearest rail of the tramway, shall be indicated by a thick dotted line on the plans on the side or sides of the line of tramway where such narrow places occur, as well as noted on the plans, and the width of the street or road at these places shall also be marked on the plans.

Note.—The section of each tramway should, where practicable, be shown on the same page as the plan.

Opening of Tramways.

Opening of tramways.

RULE XXV.—The promoters shall give to the Board of Trade at least 14 days' notice in writing of their intention to open any tramway, or portion of a tramway, and such tramway or portion of tramway shall not be opened for public traffic until an inspector appointed by the Board of Trade has inspected the same, and the Board of Trade has certified that it is fit for such traffic. The above-mentioned notice should be accompanied by the following documents, viz.:

(1.) A copy of the Act or Provisional Order authorising the construction of the tramways.

(2.) A copy or tracing of so much of the deposited plans and sections as relates to the portion of tramway proposed to be opened, distinguishing between double and single line, and showing in red ink any variations therefrom in the tramways as constructed.

(3.) A list of the local and road authorities concerned.

(4.) A diagram of the lines submitted for inspection, on a scale of about two inches to a mile.

APPENDIX III.

Extract from an Act to confirm certain Provisional Orders made by the Board of Trade under the Tramways Act, 1870, relating to Heywood Corporation Tramways, etc.

[8th August, 1902.]

WHEREAS under the authority of the Tramways Act 1870 the Board of Trade have made the several Provisional Orders set out in the schedule to this Act annexed:

And whereas a Provisional Order made by the Board of Trade under the authority of the said Act is not of any validity or force whatever until the confirmation thereof by Act of Parliament:

And whereas it is expedient that the several Provisional Orders made by the Board of Trade under the authority of the said Act and set out in the schedule to this Act annexed be confirmed by Act of Parliament:

Be it therefore enacted by the King's most Excellent Majesty by and with the advice and consent of the Lords Spiritual and Temporal and Commons in this present Parliament assembled and by the authority of the same as follows:—

Short title.

1. This Act may be cited as the Tramways Orders Confirmation (No. 2) Act 1902.

Confirmation of Orders in schedule.

2. The several Orders as amended and set out in the schedule to this Act annexed shall be and the same are hereby confirmed and all the provisions thereof in manner and form as they are set out in the said schedule shall from and after the passing of this Act have full force and validity and the dates of the same respectively shall be the date of the passing of this Act.

HEYWOOD CORPORATION.

Order authorising the Mayor Aldermen and Burgesses of the Borough of Heywood to construct Tramways in their Borough.

Preliminary.

Short title.

1. This Order may be cited as the Heywood Corporation Tramways Order 1902.

Incorporation of Acts.

2. The provisions of the Lands Clauses Acts (except with respect to the purchase and taking of lands otherwise than by agreement and with respect to the entry upon lands by the Promoters of the undertaking) and of the Tramways Act 1870 are hereby incorporated with this Order except where the same are inconsistent with or expressly varied by this order.

Interpretation.

3. The several words terms and expressions to which by the Acts in whole or in part incorporated with this Order meanings are assigned have in this Order the same respective meanings:

Provided that in this Order—

The expression "the borough" means the borough of Heywood in the county of Lancaster:

The expression "the Corporation" means the mayor aldermen and burgesses of the borough acting by the council:

The expression "the Order of 1882" means the Manchester Bury and Rochdale Tramways (Extensions) Order 1882 confirmed by the Tramways Orders Confirmation (No. 3) Act 1882:

The expression "the tramways" means the tramways and works by this Order authorised and from and after the acquisition by the Corporation of any of the tramways and works authorised by the Order of 1882 the expression shall include the tramways and works so acquired:

The expression "the undertaking" means the undertaking by this Order authorised and (if and when acquired by the Corporation) so much of the undertaking authorised by the Order of 1882 as is within the borough:

The expression "mechanical power" includes steam electrical and every other motive power not being animal power and the word "engine" includes motor.

Promoters.

4. The Corporation shall be the Promoters for the purposes of this Order and are in this Order referred to as "the Promoters."

Lands.

5. The Promoters may—

(*a*) subject to the sanction of the Local Government Board and under such conditions as they may prescribe from time to time appropriate and use for any of the purposes of this Order but subject to the provisions (if any) under which such lands were respectively acquired any lands not dedicated to public use from time to time vested in them being part of their corporate estates;

(*b*) by agreement from time to time purchase and acquire for the purposes of the undertaking such lands as they may require and may from time to time sell let or dispose of any such lands which may not be necessary for such purposes Provided that all sums received by the Promoters from the sale of such lands or from fines or premiums on leases of the same shall be applied solely in repayment of outstanding loans and that such moneys shall not be applied to the payment of instalments or to payments into the sinking fund except to such extent and upon such terms as may be approved by the Local Government Board:

Provided that they shall not at any time hold for such purposes more than five acres of land Provided also that nothing in this Order shall exonerate the Promoters from any indictment action or other proceeding for nuisance in the event of any nuisance being caused or permitted by them upon lands appropriated or taken under the powers of this section.

Construction of Tramways.

Construction of tramways.

6. The Promoters may subject to the provisions of this order—

(*a*) construct and maintain in accordance with the plans and sections deposited at the office of the Board of Trade for the purposes of this Order (which plans and sections are in this Order referred to respectively as " the deposited plans " and " the deposited sections ") the tramways herein-after described with all proper rails plates sleepers junctions turntables turnouts works and conveniences connected therewith or for the purposes thereof;

(*b*) erect or construct on any lands taken or appropriated under the powers of this Order any offices stables sheds workshops stores waiting-rooms or other buildings yards works and conveniences for the purposes of the undertaking:

Provided that nothing in this Order or in any Act wholly or in part incorporated therewith shall extend to or authorise any interference with any works of any undertakers under the Electric Lighting Acts 1882 and 1888 to which the provisions of section 15 of the Act of 1882 apply except in accordance with and subject to the provisions of that section.

The tramways authorised by this Order will be wholly situate within the borough and are as follows (that is to say):—

[Here follows description of the several tramways authorised by the Order.]

For protection of Lancashire County Council.

7. The following provisions for the protection of the Lancashire County Council (in this section called " the county council ") shall except in so far as may be otherwise agreed between the Promoters and the county council apply and have effect (that is to say):—

(1) The Promoters shall at their own expense pave so much of any main road whereon any of the tramways are laid as lies between the rail of the tramway and (where two tramways are laid in any road at a distance of not more than four feet from each other) the portion of the road between the tramways and in every case so much of the road as extends 18 inches beyond the rails of and on each side of any such tramway with granite cubes or setts or such other paving as the county council may reasonably approve and in all cases where the nearest rail of such tramway is of less distance than five feet from the outer edge of the footpath or boundary of the carriageway on either side the intervening spaces between the rail and footpath or boundary of the carriageway shall be paved in like manner to the reasonable satisfaction of the county council and the Promoters shall so long as they shall work the said tramway keep and maintain the same respectively in good repair and condition:

(2) In constructing the tramways upon or over any bridge which is repairable by the inhabitants of the county or of any hundred therein or any parts of the approaches thereto the Promoters shall not alter or interfere with the structure of such bridge or approaches unless such alteration or interference with the structure of such bridge or approaches be absolutely necessary for the purpose of constructing the tramways and in the event of any such alteration or interference the Promoters shall together with the prescribed notice submit to the county council detailed drawings and specifications showing the proposed work as affecting such bridge or approaches and if any difference arise between the Promoters and the county council as to such alteration or interference or the necessity therefor the same shall be left to the decision of the Board of Trade and the Promoters shall so construct and maintain the tramway in the road over the bridge and approaches thereto as not injuriously to affect such bridge or approaches and in the event of any injury being occasioned to such bridge or approaches or any part or parts thereof respectively by the construction of the tramway on or over the same (whether such injury shall occur either during or after construction or in the maintenance of the tramway) the county council after seven days' written notice to the Promoters except in cases of emergency when they shall give the longest notice practicable of their

intention so to do may restore such bridge and approaches or the part or parts thereof which may be injured to as good a state as they were in before such injury was occasioned at the expense of the Promoters and the Promoters shall repay the county council all reasonable expenses which they may be put to in restoring such bridge and in maintaining and repairing so much of the road over such bridge and approaches as the Promoters are liable to repair under this Order and the county council may recover from the Promoters all such expenses due as aforesaid:

(3) In case mechanical power is to be used on any portion of the tramways which are to be laid upon or over any bridge the county council may before any such tramways are open for public traffic execute such works as may be agreed between their bridgemaster and the surveyor of the Promoters or in case of difference between them as may be determined by the Board of Trade as being necessary for the strengthening of the structure of any such bridge provided such strengthening is needed for and by reason of the tramway apart from the ordinary traffic on the road in question and the county council may execute all such works at the expense of the Promoters and the county council may recover from the Promoters all moneys reasonably expended by them in execution of such works as aforesaid provided that it shall be lawful for but not binding on the Promoters to contribute such sum as may be mutually agreed upon between the Promoters and the county council towards the expenses of rebuilding altering or widening any of such bridges as aforesaid:

(4) The Promoters shall not without the consent in writing of the county bridgemaster (which consent shall not be unreasonably withheld) place erect or attach any support for any wire on or to the structure of any such bridge as aforesaid and shall on receiving three months' notice in writing (which notice shall not be unreasonably given) remove any post or support which shall at any time be so placed erected or attached as aforesaid:

(5) Nothing in this Order shall in any way limit or affect the powers of the county council to rebuild alter widen or repair the structure of any bridge upon which any work by this Order authorised shall be constructed and in the event of the county council desiring to rebuild alter widen repair or improve any such bridge or its approaches as aforesaid the county council shall not be liable to make any compensation whatever for any damage or injury to the tramways occasioned thereby and the county council shall give the Promoters one month's notice of their intention to carry out such works (except in the case of urgency caused by danger to the traffic when they shall give the longest notice practicable) and the county council may require the Promoters at their own expense to remove or temporarily support their rails wires pipes or other plant in such manner as the circumstances of the case may reasonably require and if it becomes necessary for effecting any such rebuilding altering widening repairing or improving that the working and user of such tramways be wholly or in part stopped or delayed and the county council give the Promoters seven days' clear notice in writing requiring such stoppage or delay the working and user of such tramway shall be stopped or delayed accordingly but only for so long as may be absolutely necessary for effecting such rebuilding altering widening repairing or improving and the county council shall not be liable for any compensation claims damages costs or expenses for or in respect of such stoppage or delay or the cost of relaying the Promoters' rails wires pipes or other plant.

For protection of Heywood and Middleton Water Board.

8.—(1) Sections 30 32 and 33 of the Tramways Act 1870 shall extend and apply to the Heywood and Middleton Water Board (in this section called "the board") with reference to the pipes and apparatus belonging to them in like manner as the same apply to a company or person being the owner of water mains or pipes tubes wires or apparatus Provided that all works or interference under section 30 of the Tramways Act 1870 or otherwise with or in connexion with such pipes and apparatus shall if the Board so desire be made or executed by them upon the request and at the cost of the Promoters.

(2) If any injury or damage shall be occasioned to any water pipes or other metallic pipes structures or substances of the board by fusion or electrolytic action caused by any currents generated or used by the Corporation for the purpose of electric traction on the tramways the Corporation shall make full compensation to the board for such injury or damage.

For protection of Lancashire and Yorkshire Railway Company

9. For the protection of the Lancashire and Yorkshire Railway Company (in this section called "the company") the following provisions shall unless otherwise agreed between the Promoters and the company be observed and have effect in relation to the construction and maintenance of the tramways and works connected therewith and of any works for the purpose of working the tramways by mechanical power (that is to say):—

(1) In this section the word "apparatus" includes posts brackets electric conductors wires apparatus and any similar appliances to be used as or for the purposes of a motive power for the carriages running on the tramways and includes also any subways tunnels tubes and openings for the purposes of such apparatus:

(2) Before commencing any works on or over any bridge or the approaches thereto or other work belonging to or maintainable by the company the Promoters shall give fourteen days' notice in writing to the company of their intention to execute such works and such notice shall be accompanied by plans sections and specifications showing the nature and extent of the intended works:

(3) The Promoters shall so construct and maintain and use the tramways and apparatus as

not to alter or interfere with or injuriously affect the structure of any such bridge or of the approaches thereto:

(4) In the event of any injury being caused to any such bridge or the approaches thereto by the construction maintenance repairing user or removal of the tramways or apparatus the company may at the reasonable expense in all things of the Promoters after giving (except in cases of emergency when they shall give the longest notice possible) not less than seven clear days' notice in writing of their intention so to do restore such bridge and approaches or the part or parts thereof which may be so injured to as good a state and condition as they were in before such injury was occasioned:

(5) All works which may be necessary in constructing and maintaining the tramways or apparatus over any such bridge and the approaches thereto shall be constructed and maintained in all things at the expense of the Promoters and under the superintendence and to the reasonable satisfaction of the engineer of the company if such engineer shall give such superintendence:

(6) In case it shall become necessary in consequence of the existence or user of the tramways or apparatus to strengthen the fabric of any such bridge the company may after giving to the Promoters fourteen clear days' notice thereof execute such works as may be necessary but in all things at the reasonable expense of the Promoters:

(7) The sleepers and other materials forming the substructure of the tramways where the same cross any such bridge over the railway or are laid along the approaches thereto shall subject to the provisions of this section be such as shall be reasonably approved of by the company:

(8) Whenever and so often as the company shall require under their existing powers to lengthen strengthen reconstruct alter or repair any bridge over which any tramway of the Promoters is laid or the approaches thereto or whenever and so often as the company shall find it necessary in consequence of the existence or user of any such tramway to strengthen the fabric of any such bridge and the company shall in any of such events find it necessary for effecting any of such purposes that the working and user of any of the said tramways over any such bridge or approaches shall be wholly or partly stopped or delayed or that the tramways or any apparatus connected therewith shall be wholly or in part temporarily diverted taken up or removed and shall (except in cases of emergency when they shall give the longest notice practicable) give to the Promoters seven clear days' notice in writing requiring such stoppage delay or diversion taking up or removal the working or user of the tramways shall be stopped or delayed or the tramways or apparatus shall be diverted or taken up or removed accordingly by and at the expense in all things of the Promoters and under the superintendence of the engineer of the company (if such engineer shall give such superintendence) but only for so long as may be absolutely necessary for effecting such purpose and the company shall not be liable for any compensation claims demands damages costs and expenses for or in respect of such stoppage or delay or in any way relating thereto If the Promoters after such notice make default in diverting taking up or removal of any such tramway or apparatus the company may at the expense of the Promoters effect such diversion taking up or removal:

(9) The Promoters shall be responsible for and make good to the company all losses damages and expenses which may be occasioned to the company or any of their works or property by or by reason of the execution or failure of any of the works by this Order authorised:

(10) The Promoters shall not commence any works for the purpose of carrying overhead trolley or other wires for working the tramways over any railway of the company until after one month's notice in writing to the company and the company may on receipt of such notice execute all works necessary for and incidental to the removal of their electric telegraphic telephonic and signalling wires and apparatus over the road along which the tramway is proposed to be laid and replacing the same underground or make such other alterations in such wires or apparatus as may be reasonably necessary for the protection thereof or for avoiding danger from the breaking or falling of wires and the expenses incurred by the company in carrying out the provisions of this subsection shall be repaid to the company by the Promoters on demand:

(11) If any difference shall arise under this section between the Promoters and the company touching anything to be done or omitted to be done or not to be done or the reasonableness of any requirements or of any charges or in any manner in connexion with the foregoing provisions of this section the matter in difference shall unless otherwise agreed be determined by a referee to be nominated by the Board of Trade under section 33 of the Tramways Act 1870.

Gauge and width of carriages.

10. The tramways shall be constructed on a gauge of four feet eight and a half inches or such other gauge as may from time to time be determined by the Board of Trade on the application of the Promoters Provided always that in the event of the tramways being constructed on a less gauge than four feet eight and a half inches so much of section 34 of the Tramways Act 1870 as limits the extent of the carriages used on any tramways beyond the outer edge of the wheels of such carriages shall not apply to carriages used on the tramways but in that case no engine or carriage used on the tramways shall exceed six feet six inches in width or such other width as may from time to time be prescribed by the Board of Trade.

Provisions as to construction of tramways.

11. In addition to the requirements of section 26 of the Tramways Act 1870 the Promoters shall lay before the Board of Trade a plan showing the proposed mode of constructing laying down maintaining or renewing the tramways and a statement of the materials intended to be used therein and the Promoters shall not commence the construction laying down maintenance or renewal of any of the tramways or part of any of the tramways respectively except for the purpose of necessary repairs until such plan and statement have been approved by the Board of Trade and after such approval the works shall be executed in accordance in all respects with such plan and statement and in places where the Promoters are not the sole road authority under the superintendence and to the reasonable satisfaction of the surveyor of the road authority as provided by the said section.

Rails of tramways.

12. The rails of the tramways shall be such as the Board of Trade may approve.

Penalty for not maintaining rails and roads in good condition.

13.—(1) The Promoters shall at all times maintain and keep in good condition and repair and so as not to be a danger or annoyance to the ordinary traffic the rails of the tramways and the substructure upon which the same rest and if the Promoters at any time fail to comply with this provision or with the provisions of section 28 of the Tramways Act 1870 they shall be subject to a penalty not exceeding five pounds for every day on which such non-compliance continues.

(2) In case it is represented in writing to the Board of Trade by the road authority of any district in which the tramways or any portion thereof are or is situate or by twenty inhabitant ratepayers of the borough that the Promoters have made default in complying with the provisions in this section contained or with any of the requirements of section 28 of the Tramways Act 1870 the Board of Trade may if they think fit direct an inspection by an officer to be appointed by the said Board and if such officer report that the default mentioned in such representation has been proved to his satisfaction then and in every such case a copy of such report certified by a secretary or assistant secretary of the Board of Trade may be adduced as evidence of such default and of the liability of the Promoters to such penalty or penalties in respect thereof as is or are by this section imposed.

Tramways to be kept on level of surface of road.

14. If the Promoters or any other road authority hereafter alter the level of any road along or across which any part of the tramways is laid or authorised to be laid the Promoters may and shall from time to time alter or (as the case may be) lay their rails so that the uppermost surface thereof shall be on a level with the surface of the road as altered.

Alteration of tramways.

15. The Promoters may with the consent of the Board of Trade lay down double lines in lieu of single or interlacing lines or single lines in lieu of double or interlacing lines or interlacing lines in lieu of double or single lines on any of the tramways and may with the like consent subject in places where the Promoters may not be the road authority to the approval of that authority alter the position in the road of any of the tramways or any part thereof respectively Provided that the uppermost surface thereof shall be on a level with the surface of the road:

Provided further that in exercise of the powers of this section no rail shall be so laid that a less space than nine feet six inches shall intervene between it and the outside of the footpath on either side of the road if one third of the owners or one third of the occupiers of the premises abutting on the place where such less space shall intervene shall by writing under their hands addressed and delivered to the Promoters within three weeks after receiving from the Promoters notice of their intention (which notice the Promoters shall give one month before commencing any alterations under this section) express their objection thereto.

Cross-over roads to be constructed in certain cases.

16. Where in any road in which a double line of tramway is laid there shall be less width between the outside of the footpath on either side of the road and the nearest rail of the tramway than nine feet six inches the Promoters shall if and where required by the Board of Trade construct a cross-over or roads connecting the one tramway with the other and by the means of such cross-over or roads the traffic shall when necessary be diverted from one tramway to the other.

Additional cross-over roads &c. may be made where necessary.

17. The Promoters may subject to the provisions of this Order from time to time make maintain alter and remove all such cross-over roads passing-places sidings junctions and other works in addition to those particularly specified in and authorised by this Order as they find necessary for the efficient working of the tramways or for forming junctions with other tramways or for providing access to any warehouses stables or carriage-houses or works of the Promoters but in places where the Promoters may not be the road authority the same shall only be made subject to the approval of the road authority Provided that in the construction of any such works no rail shall be so laid that a less space than nine feet six inches shall intervene between it and the outside of the footpath on either side of the road if one third of the owners or one third of the occupiers of the premises abutting on the place where such less space shall intervene shall by writing under their hands addressed and delivered to the Promoters within three weeks after receiving from the Promoters notice of their intention (which notice the Promoters shall give one month before commencing any works under this section) express their objection thereto.

Temporary tramways may be made when necessary.

18. Where by reason of the execution of any work affecting the surface or soil of any road along which any of the tramways are laid it is in the opinion of the Promoters necessary or expedient temporarily to remove or discontinue the use of such tramway or any part thereof the Promoters may construct in the same or any adjacent road and maintain so long as occasion may require a temporary tramway or temporary tramways in lieu of the tramway or part of the tramway so removed or discontinued subject in places in which the Promoters may not be the road authority to the approval of the road authority and to such regulations as that authority may make.

Application of road materials excavated in construction of works.

19.—(1) Any paving metalling or material excavated by the Promoters in the construction of any works under the authority of this Order from any road under their jurisdiction or control shall absolutely vest in and belong to the Promoters and may be dealt with removed and disposed of by them in such manner as they may think fit.

(2) Any paving metalling or material excavated by the promoters in the construction of the tramways from any road under the jurisdiction or control of any road authority other than the promoters may be applied by the Promoters so far as may be necessary in or towards the reinstating of such road and the maintenance for six months after completion of any of the tramways within the district of such road authority of so much of the roadway on either side of such tramways as the Promoters are by this Order required to maintain and the Promoters shall if so required deliver the surplus paving metalling or material not used or required to be retained for the purposes aforesaid to the surveyor for the time being of such road authority or to such person as he may appoint to receive the same at such place as he may direct Provided that if within seven days after the setting aside of the surplus arising from the excavation of any such paving metalling or material and notice duly given such surplus is not removed by such surveyor or by some other person named by him for that purpose such surplus paving metalling or material shall absolutely vest in and belong to the Promoters and may be dealt with removed and disposed of by them in such manner as they may think fit. Any difference between the Promoters and any road authority or surveyor or other person with reference to any of the matters aforesaid shall be settled by a referee to be nominated by the Board of Trade on the application of either party.

Tramways not to be opened until certified by Board of Trade.

20. The tramways shall not be opened for public traffic until the same have been inspected and certified to be fit for such traffic by the Board of Trade.

Motive Power.

Provisions as to motive power.

21. The carriages used on the tramways may be moved by animal power or subject to the following provisions by mechanical power (that is to say):—

(1) The mechanical power shall not be used except with the consent of and according to a system approved by the Board of Trade:

(2) The Board of Trade shall make regulations (in this Order referred to as "the Board of Trade regulations") for securing to the public all reasonable protection against danger arising from the use under this Order of mechanical power on the tramways and for regulating the use of electrical power:

(3) The Promoters or any company or person using any mechanical power on the tramways contrary to the provisions of this Order or of the Board of Trade regulations shall for every such offence be liable to a penalty not exceeding ten pounds and also in the case of a continuing offence to a further penalty not exceeding five pounds for every day during which such offence is continued after conviction thereof:

(4) The Board of Trade if they are of opinion—

(*a*) that the Promoters or such company or person have or has made default in complying with the provisions of this Order or of the Board of Trade regulations whether a penalty in respect of such non-compliance has or has not been recovered; or

(*b*) that the use of mechanical power as authorised under this Order is a danger to the passengers or the public;

may by order direct the Promoters or such company or person to cease to use such mechanical power or permit the same to be continued only subject to such conditions as the Board of Trade may impose and the Promoters or such company or person shall comply with every such order In every such case the Board of Trade shall make a special report to Parliament notifying the making of such order.

Mechanical power works.

22. For the purpose of working any of the tramways by mechanical power the Promoters and their lessees subject to the provisions of this Order (and as to the lessees subject to the terms of their lease) may—

(*a*) construct provide maintain and use on any lands appropriated or acquired under the powers of this Order stations for generating electrical power and may provide on such lands as aforesaid in connexion with such stations or with any generating station constructed under powers already conferred upon the Promoters all necessary or proper machinery dynamos engines buildings works and conveniences;

(*b*) place construct erect lay down make and maintain on above or below the surface of any street or road posts brackets electric conductors wires apparatus subways tunnels cables tubes and openings;

(*c*) with the consent of the owners and occupiers of any houses or buildings affix to such houses or buildings or maintain brackets wires and apparatus.

Mechanical power works to be subject to Tramways Act 1870

23. All works to be executed by the Promoters or their lessees in any street or road for working the tramways by mechanical power in pursuance of the powers of this Order shall be deemed to be works of a tramway subject in all respects (save as by this Order otherwise expressly provided) to the provisions of the Tramways Act 1870 as in this Order incorporated as if they had been therein expressly mentioned.

24. As to bye-laws regulating engines and carriages, emission of smoke, &c.

25. As to rate of speed.

Special provisions as to use of electrical power.

26. The following provisions shall apply to the use of electrical power under this Order unless such power is entirely contained in and carried along with the carriages:—

(1) The Promoters shall employ either insulated returns or uninsulated metallic returns of low resistance:

(2) The Promoters shall take all reasonable precautions in constructing placing and maintaining their electric lines and circuits and other works of all descriptions and also in working their undertaking so as not injuriously to affect by fusion or electrolytic action any gas or water pipes or other metallic pipes structures or substances or to interfere with the working of any wire line or apparatus from time to time used for the purpose of transmitting electrical power or of telegraphic telephonic or electric communication or the currents in such wire line or apparatus:

(3) The electrical power shall be used only in accordance with the Board of Trade regulations and in such regulations provision shall be made for preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes structures or substances and for minimising as far as is reasonably practicable injurious interference with the electric wire lines and apparatus of other parties and the currents therein whether such lines do or do not use the earth as a return:

(4) The Promoters shall be deemed to take all reasonable precautions against interference with the working of any wire line or apparatus if and so long as they adopt and employ at the option of the Promoters either such insulated returns or such uninsulated metallic returns of low resistance and such other means of preventing injurious interference with the electric wires lines and apparatus of other parties and the currents therein as may be prescribed by the Board of Trade regulations and in prescribing such means the Board shall have regard to the expenses involved and to the effect thereof upon the commercial prospects of the undertaking:

(5) At the expiration of two years from the passing of the Act confirming this Order the provisions of this section shall not operate to give any right of action in respect of injurious interference with any electric wire line or apparatus or the currents therein unless in the construction erection maintaining and working of such wire line and apparatus all reasonable precautions including the use of an insulated return have been taken to prevent injurious interference therewith and with the currents therein by or from other electric currents:

(6) If any difference arises between the Promoters and any other party with respect to anything herein-before in this section contained such difference shall unless the parties otherwise agree be determined by the Board of Trade or at the option of the Board by an arbitrator to be appointed by the Board and the costs of such determination shall be in the discretion of the Board or of the arbitrator as the case may be:

(7) The expression "the Promoters" in this section shall include their lessees and any person owning working or running carriages over any tramways of the Promoters.

For protection of Postmaster-General.

27.—(A) Notwithstanding anything in this Order contained if any of the works by this Order authorised involves or is likely to involve any alteration of any telegraphic line belonging to or used by His Majesty's Postmaster-General the provisions of section 7 of the Telegraph Act 1878 shall apply (instead of the provisions of section 30 of the Tramways Act 1870) to any such alteration.

(B) In the event of the tramways or any part thereof being worked by electricity the following provisions shall have effect:—

(1) The Promoters shall construct their electric lines and other works of all descriptions and shall work the undertaking in all respects with due regard to the telegraphic lines from time to time used or intended to be used by the Postmaster-General and the currents in such telegraphic lines and shall use every reasonable means in the construction of their electric lines and other works of all descriptions and the working of the undertaking to prevent injurious affection whether by induction or otherwise to such telegraphic lines or the currents therein Any difference which arises between the Postmaster-General and the Promoters as to compliance with this subsection shall be determined by arbitration:

(2) If any telegraphic line of the Postmaster-General is injuriously affected by the construction by the Promoters of their electric lines and works or by the working of the undertaking the Promoters shall pay the expense of all such alterations in the telegraphic lines of the Postmaster-General as may be necessary to remedy such injurious affection:

(3) Before any electric line is laid down or any act or work for working the tramways by electricity is done within ten yards of any part of a telegraphic line of the Postmaster-General (other than repairs) the Promoters or their agents not more than twenty-eight nor less than fourteen days before commencing the work shall give written notice to the Postmaster-General specifying the course of the line and the nature of the work including the gauge of any wire and the Promoters and their agents shall conform with such reasonable requirements (either general or special) as may from time to time be made by the Postmaster-General for the purpose of preventing any telegraphic line of the Postmaster-General from being injuriously affected by the said act or work Any difference which arises between the Postmaster-General and the Promoters or their agents with respect to any requirements so made shall be determined by arbitration:

(4) If any telegraphic line of the Postmaster-General situate within one mile of any

portion of the works of the Promoters is injuriously affected and he is of opinion that such injurious affection is or may be due to the construction of the works of the Promoters or to the working of the undertaking the engineer-in-chief of the Post Office or any person appointed in writing by him may at all times when electrical energy is being generated by the Promoters enter any of the works of the Promoters for the purpose of inspecting the plant of the Promoters and the working of the same and the Promoters shall in the presence of such engineer-in-chief or such appointed person as aforesaid make any electrical tests required by the Postmaster-General and shall produce for the inspection of the Postmaster-General the records kept by the Promoters pursuant to the Board of Trade regulations:

(5) In the event of any contravention of or wilful non-compliance with this section by the Promoters or their agents the Promoters shall be liable to a fine not exceeding ten pounds for every day during which such contravention or non-compliance continues or if the telegraphic communication is wilfully interrupted not exceeding fifty pounds for every day on which such interruption continues:

(6) Provided that nothing in this section shall subject the Promoters or their agents to a fine under this section if they satisfy the court having cognisance of the case that the immediate doing of any act or the execution of any work in respect of which the penalty is claimed was required to avoid an accident or otherwise was a work of emergency and that they forthwith served on the postmaster or sub-postmaster of the postal telegraph office nearest to the place where the act or work was done a notice of the execution thereof stating the reason for doing or executing the same without previous notice:

(7) For the purposes of this section a telegraphic line of the Postmaster-General shall be deemed to be injuriously affected by an act or work if telegraphic communication by means of such line is whether through induction or otherwise in any manner affected by such act or work or by any use made of such work:

(8) For the purposes of this section and subject as therein provided sections 2 10 11 and 12 of the Telegraph Act 1878* shall be deemed to be incorporated with this Order:

(9) The expression "electric line"† has the same meaning in this section as in the Electric Lighting Act 1882:

(10) Any question or difference arising under this section which is directed to be determined by arbitration shall be determined by an arbitrator appointed by the Board of Trade on the application of either party whose decision shall be final and sections 30 to 32 both inclusive of the Regulation of Railways Act 1868 shall apply in like manner as if the Promoters or their agents were a company within the meaning of that Act:

(11) Nothing in this section contained shall be held to deprive the Postmaster-General of any existing right to proceed against the Promoters by indictment action or otherwise in relation to any of the matters aforesaid:

(12) In this section the expression "the Promoters" includes their lessees and any person owning working or running carriages over the tramways (or any part thereof) of the Promoters.

28.
29. } As to traffic upon the tramways.
30.

31.
32.
33.
34. } As to rates and charges, cheap fares for labouring classes, and periodical revision of rates.
35.
36.
37.

Application of Order to existing tramways.

38. Nothing contained in this Order shall authorise the Promoters to interfere with any of the tramways constructed under the Order of 1882 until the same have been acquired by the Promoters except with the consent of the owners thereof and upon the acquisition by the Promoters of any of the tramways or parts of tramways authorised by the Order of 1882 and constructed within the borough the provisions of that Order and of the Tramways Orders Confirmation (No. 3) Act 1882 shall cease to apply to the tamways and parts of tramways so acquired and the provisions of this Order shall so far as they are applicable in that behalf extend and apply mutatis mutandis to and in relation to such tramways or parts of tramways as if the same had been tramways authorised by this Order and the Conveyance of Mails Act 1893 shall extend and apply to such tramways or parts of tramways as if the same had been authorised by an Act of Parliament passed after the first day of January one thousand eight hundred and ninety-three and to the Promoters as the body or person owning or working such tramways.

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*These relate to penalties, legal proceedings and forms and service of notices.

†The expression "electric line" means a wire or wires, conductor or other means used for the purpose of conveying, transmitting, or distributing electricity with any casing, coating, covering, tube, pipe or insulator enclosing, surrounding or supporting the same, or any part thereof, or any apparatus connected therewith for the purpose of conveying, transmitting or distributing electricity or electric currents.

Power to corporation to work tramways.

39. Notwithstanding anything in the Tramways Act 1870 to the contrary the Corporation may place and run carriages on and may work and may demand and take rates and charges in respect of the tramways and in respect of the use of such carriages and may provide such stables buildings carriages trucks horses harness engines machinery apparatus steam cable electrical and other plant appliances and conveniences as may be requisite or expedient for the convenient working or user of the said tramways by animal or mechanical power and in such case the several provisions in this Order contained relating to the working of the tramways and the taking of rates and charges therefor shall extend and apply mutatis mutandis to and in relation to the Corporation and the Corporation may work such tramways and demand and recover such rates and charges accordingly but nothing in this section shall empower the Corporation to construct any station for generating electrical power nor to create or permit a nuisance.

40. }
41. } Regulations and working agreements.

42. }
43. }
44. }
45. } Clauses dealing with miscellaneous matters, mortgages, notices, audits, and provisions
46. } as to arbitration.
47. }
48. }
49. }

[Here follows Schedule of Rates and charges and regulations as to charges for fractional quantities.]

APPENDIX IV.

LIGHT RAILWAYS ACT, 1896.

[59 & 60 Vict. Ch. 48.]

Extracts from an Act to facilitate the Construction of Light Railways in Great Britain.*

[14th August 1896.]

Establishment of Light Railway Commission.

1.—(1.) For the purpose of facilitating the construction and working of light railways in Great Britain, there shall be established a commission, consisting of three commissioners, to be styled the Light Railway Commissioners, and to be appointed by the President of the Board of Trade.

(2.) It shall be the duty of the Light Railway Commissioners to carry this Act into effect, and to offer, so far as they are able, every facility for considering and maturing proposals to construct light railways.

(3.) If a vacancy occurs in the office of any of the Light Railway Commissioners by reason of death, resignation, incapacity, or otherwise, the President of the Board of Trade may appoint some other person to fill the vacancy, and so from time to time as occasion may require.

(4.) There shall be paid to one of the Commissioners such salary, not exceeding one thousand pounds a year, as the Treasury may direct.

(5.) The Board of Trade may, with the consent of the Treasury as to number and remuneration, appoint and employ such number of officers and persons as they think necessary for the purpose of the execution of the duties of the Light Railway Commissioners under this Act, and may remove any officer or person so appointed or employed.

(6.) The said salary and remuneration, and all expenses of the Light Railway Commissioners incurred with the sanction of the Treasury in the execution of this Act shall, except so far as provision is made for their payment by or under this Act, be paid out of moneys provided by Parliament.

(7.) The Commissioners may act by any two of their number.

(8.) The powers of the Light Railway Commissioners shall, unless continued by Parliament, cease on the thirty-first day of December one thousand nine hundred and one.

Application for orders authorising light railways.

2. An application for an order authorising a light railway under this Act shall be made to the Light Railway Commissioners, and may be made—

(*a*) by the council of any county, borough, or district, through any part of which the proposed railway is to pass; or

(*b*) by any individual, corporation, or company; or

(*c*) jointly by any such councils, individuals, corporations, or companies.

Powers of local authorities under order

3.—(1.) The council of any county, borough, or district, may if authorised by an order under this Act—

(*a*) undertake themselves to construct and work, or to contract for the construction or working of, the light railway authorised;

(*b*) advance to a light railway company, either by way of loan or as part of the share capital of the company, or partly in one way and partly in the other, any amount authorised by the order;

(*c*) join any other council or any person or body of persons in doing any of the things above mentioned; and

(*d*) do any such other act incidental to any of the things above mentioned as may be authorised by the order.

(2.) Provided that—

(*a*) an order authorising a council to undertake to construct and work or to contract for the construction or working of a light railway, or to advance money to a light railway company, shall not be made except on an application by the council made in pursuance of a special resolution passed in manner directed by the First Schedule to this Act; and

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*The full text of this Act can be obtained through a bookseller; price 2½d.

(*b*) a council shall not construct or work or contract for the construction or working of any light railway wholly or partly outside their area, or advance any money for the purpose of any such railway, except jointly with the council of the outside area, or on proof to the satisfaction of the Board of Trade that such construction, working, or advance is expedient in the interests of the area of the first-mentioned council, and in the event of their being authorised so to do their expenditure shall be so limited by the order as not to exceed such amount as will, in the opinion of the Board of Trade, bear due proportion to the benefit which may be expected to accrue to their area from the construction or working of the railway.

4. 5. 6. As to loans and special advances by the Treasury and limitation on amount of advance by National Debt Commissioners.

Consideration of application by Light Railway Commissioners.

7.—(1.) Where an application for authorising a light railway under this Act is made to the Light Railway Commissioners, those Commissioners shall, in the first instance, satisfy themselves that all reasonable steps have been taken for consulting the local authorities, including road authorities, through whose areas the railway is intended to pass, and the owners and occupiers of the land it is proposed to take, and for giving public notice of the application, and shall also themselves by local inquiry and such other means as they think necessary possess themselves of all such information as they may consider material or useful for determining the expediency of granting the application.

(2.) The applicants shall satisfy the commissioners that they have

(*a*) published once at least in each of two consecutive weeks, in some newspaper circulating in the area or some part of the area through which the light railway is to pass, an advertisement describing shortly the land proposed to be taken and the purpose for which it is proposed to be taken, naming a place where a plan of the proposed works and the lands to be taken, and a book of reference to the plan, may be seen at all reasonable hours, and stating the quantity of land required; and

(*b*) served notice in the prescribed manner on every reputed owner, lessee, and occupier of any land intended to be taken, describing in each case the land intended to be taken, and inquiring whether the person so served assents to or dissents from the taking of his land, and requesting him to state any objections he may have to his land being taken.

The plan and book of reference shall be in the prescribed form, and for the purposes of this section the expression "prescribed" shall mean prescribed by rules made under this Act.

(3.) The Commissioners shall before deciding on an application give full opportunity for any objections to the application to be laid before them, and shall consider all such objections, whether made formally or informally.

(4.) If after consideration the Commissioners think that the application should be granted, they shall settle any draft order submitted to them by the applicants for authorising the railway, and see that all such matters (including provisions for the safety of the public and particulars of the land proposed to be taken) are inserted therein, as they think necessary for the proper construction and working of the railway.

(5.) The order of the Light Railway Commissioners shall be provisional only, and shall have no effect until confirmed by the Board of Trade in manner provided by this Act.

(6.) Where an application for a light railway has been refused by the Light Railway Commissioners, the applicants, if the council of any county, borough, or district, may appeal against such refusal to the Board of Trade, who may, at any time if they think fit, remit the application or any portion thereof to the said Commissioners for further consideration with or without special instructions.

Submission of order to Board of Trade for confirmation.

8.—(1.) The Commissioners shall submit any order made by them under this Act to the Board of Trade for confirmation, accompanied by such particulars and plans as may be required by the Board, and shall also make and lay before the Board with the order a report stating the objections which have been made to the application, and the manner in which they have been dealt with, and any other matters in reference to the order which the Commissioners may think fit to insert in the report.

(2.) The Board of Trade shall give public notice of any order so submitted to them in such manner as they think best for giving information thereof to persons interested, and shall also state in the notice that any objections to the confirmation of the order must be lodged with the Board and the date by which those objections must be lodged.

Consideration of order by Board of Trade.

9.—(1.) The Board of Trade shall consider any order submitted to them under this Act for confirmation with special reference to—

(*a*) the expediency of requiring the proposals to be submitted to Parliament; and

(*b*) the safety of the public; and

(*c*) any objection lodged with them in accordance with this Act.

(2.) The Light Railway Commissioners shall, so far as they are able, give to the Board of Trade any information or assistance which may be required by the Board for the purpose of considering any order submitted to them or any objection thereto.

(3.) If the Board of Trade on such consideration are of opinion that by reason of the magnitude of the proposed undertaking, or of the effect thereof on the undertaking of any railway company existing at the time, or for any other special reason relating to the undertaking, the proposals of the promoters ought to be submitted to Parliament, they shall not confirm the order.

(4.) The Board of Trade shall modify the provisions of the order for ensuring the safety of the public in such manner as they consider requisite or expedient.

(5.) If any objection to the order is lodged with the Board of Trade and not withdrawn, the Board of Trade shall consider the objection and give to those by whom it is made an opportunity of being heard, and if after consideration they decide that the objection should be upheld, the Board shall not confirm the order, or shall modify the order so as to remove the objection.

(6.) The Board of Trade may at any time, if they think fit, remit the order to the Light Railway Commissioners for further consideration, or may themselves hold or institute a local inquiry, and hear all parties interested.

Confirmation of order by Board of Trade.

10. The Board of Trade may confirm the order with or without modifications as the case may require, and an order so confirmed shall have effect as if enacted by Parliament, and shall be conclusive evidence that all the requirements of this Act in respect of proceedings required to be taken before the making of the Order have been complied with.

Provisions which may be made by the order.

11. An order under this Act may contain provisions consistent with this Act for all or any of the following purposes—

(*a*) the incorporation, subject to such exceptions and variations as may be mentioned in the order, of all or any of the provisions of the Clauses Acts as defined by this Act. Provided that where it appears to the Board of Trade that variations of the Lands Clauses Acts are required by the special circumstances of the case, the Board of Trade shall make a special report to Parliament on the subject, and that nothing in this section shall authorise any variation of the provisions of the Lands Clauses Acts with respect to the purchase and taking of land otherwise than by agreement; and

(*b*) the application, if and so far as may be considered necessary, of any of the enactments mentioned in the Second Schedule to this Act (being enactments imposing obligations on railway companies with respect to the safety of the public and other matters); and

(*c*) giving the necessary powers for constructing and working the railway, including power to make agreements with railway and other companies for the purpose; and

(*d*) giving any railway company any power required for carrying the order into effect; and

(*e*) the constitution as a body corporate of a company for the purpose of carrying out the objects of the order; and

(*f*) the representation on the managing body of the railway of any council who advance, or agree to advance, any money for the purpose of the railway; and

(*g*) authorising a council to advance or borrow money for the purposes of the railway and limiting the amount to be so advanced or borrowed, and regulating the terms on which any money is to be so advanced or borrowed; and

(*h*) the manner in which the profits are to be divided, where an advance is made by a council to a light railway company as part of the share capital of the company; and

(*i*) the proper audit of the accounts of the managing body of the railway where the managing body is not a local authority and the time within which the railway must be constructed; and

(*j*) fixing the maximum rates and charges for traffic; and

(*k*) in the case of a new company, requiring the company to make a deposit, and providing for the time of making and the application of the deposit; and

(*l*) empowering any local authority to acquire the railway; and

(*m*) any other matters, whether similar to the above or not, which may be considered ancillary to the objects of the order or expedient for carrying those objects into effect.

Application of general Railway Acts.

12.—(1.) The Clauses Acts, as defined by this Act, and the enactments mentioned in the Second Schedule to this Act, shall not apply to a light railway authorised under this Act except so far as they are incorporated or applied by the order authorising the railway.

(2.) Subject to the foregoing provisions of this Act and to any special provisions contained in the order authorising the railway, the general enactments relating to railways shall apply to a light railway under this Act in like manner as they apply to any other railway; and for the purposes of those enactments, and of the Clauses Acts so far as they are incorporated or applied by the Order authorising the railway, the light railway company shall be deemed a railway company, and the order under this Act a special Act, and any provision thereof a special enactment. Provided that a light railway shall not be deemed to be a railway within the meaning of the Railway Passenger Duty Act, 1842, and that no duties shall hereafter be levied in respect of passengers conveyed on a light railway constructed under this Act in respect of the conveyance of such passengers upon such railway.

5 & 6 Vict. c. 79.

13. }
14. } As to settling amount and payment of purchase money or compensation.

Provisions as to Board of Trade.
37 & 38 Vict. c. 40.

15.—(1.) If the Board of Trade hold a local inquiry for the purposes of this Act, Part I. of the Board of Trade Arbitrations, &c. Act, 1874, shall apply to any inquiry so held as if—

(*a*) the inquiry was held on an application made in pursuance of a special Act; and

(*b*) the parties making the application for the order authorising the light railway, and in the case of an inquiry held with reference to an objection made to any such application the persons making the objection in addition, were parties to the application within the meaning of section three of the Act.

(2.) The Board of Trade may make such rules as they think necessary for regulating the procedure under this Act, whether before the Board of Trade or before the Light Railway Commissioners, and any other matters which they may think expedient to regulate by rule for the purpose of carrying this Act into effect.

(3.) There shall be charged in respect of proceedings under this Act before the Board of Trade or the Light Railway Commissioners such fees as may be fixed by the Treasury on the recommendation of the Board of Trade.

(4.) Any expenses of the Board of Trade under this Act shall, except so far as provision is made for their payment by or under this Act, be defrayed out of moneys provided by Parliament.

(5.) The Board of Trade shall present to Parliament annually a report of their proceedings and of the proceedings of the Light Railway Commissioners under this Act.

Expenses of local authorities.

16.—(1.) The council of any county, borough, or district may pay any expenses incurred by them and allowed by the Light Railway Commissioners with reference to any application for an order authorising a light railway under this Act, in the case of a county council as general expenses, in the case of a borough council out of the borough fund or rate, and in the case of a district council other than a borough council as general expenses under the Public Health Acts.

Provided that any expenses incurred by a county council under this Act may be declared by the order authorising the railway or, in the event of an unsuccessful application for such an order, by the Light Railway Commissioners, to be exclusively chargeable on certain parishes only in the county, and those expenses shall be levied accordingly as expenses for a special county purpose under the Local Government Act, 1888.

51&52 Vict. c. 41.

(2.) Where the council of any county, borough, or district are authorised to expend any money by an order authorising a light railway under this Act, they may raise the money required,—

(*a*) if the expenditure is capital expenditure, by borrowing in manner authorised by the order; and

(*b*) if the expenditure is not capital expenditure, as if it was on account of the expenses of an application under this Act.

(3.) The Board of Trade may from time to time on the application of any council extend, subject to the limitations of this Act, the limit of the amount which the council are authorised by an order under this Act to borrow, or to advance to a light railway company, and the limit so extended shall be substituted for the limit fixed by the order.

(4.) Where an order under this Act authorises any council to borrow for the purposes of a light railway, suitable provision shall be made in the order for requiring the replacement of the money borrowed within a fixed period not exceeding sixty years, either by means of a sinking fund or otherwise.

(5.) Any profits made by a council in respect of a light railway shall be applied in aid of the rate out of which the expenses of the council in respect of the light railway are payable.

(6.) Where a rate is levied for meeting any expenditure under this Act, the demand note for the rate shall state, in a form prescribed by the Local Government Board, the proportion of the rate levied for that expenditure.

Joint committees.

17.—(1.) The councils of any county, borough, or district, may appoint a joint committee for the purpose of any application for an order authorising a light railway under this Act, or for the joint construction or working of a light railway, or for any other purpose in connexion with such a railway for which it is convenient that those councils should combine.

51 & 52 Vict. c. 41.
56 & 57 Vict. c. 73.

(2.) The provisions of the Local Government Act, 1888, or of the Local Government Act, 1894, as the case may be, with respect to joint committees, shall apply to any joint committee appointed for the purpose of this Act by any councils who could appoint a joint committee under those Acts, but where the councils have no power under those Acts to appoint a joint committee the provisions in the Third Schedule to this Act shall apply.

18. Railway Company may work railway as a Light Railway.

19.
20. Power of owners to grant lands, and provisions as to commons and preservation of
21. scenery and objects of historical interest.
22.

Junctions with existing railways.

23. Any junction of a light railway authorised under this Act with any existing railway shall so far as is in the opinion of the Board of Trade reasonably practicable avoid interference with lines of rails used for passenger traffic.

Amendment of order.

24. An order authorising a light railway under this Act may be altered or added to by an amending order made in like manner and subject to the like provisions as the original order.

Provided that—

(*a*) the amending order may be made on the application of any authority or person; and

(*b*) the Board of Trade, in considering the expediency of requiring the proposals for amending the order to be submitted to Parliament, shall have regard to the scope and provisions of the original order; and

(*c*) the amending order shall not confer any power to acquire the railway except with the consent of the owners of the railway.

Provisions as to telegraphs.
41 & 42 Vict. c 76.

25. The definition of "Act of Parliament" in the Telegraph Act, 1878, shall include an order authorising a light railway under this Act.

26. This Act shall apply to Scotland with the following modifications:—

Application to Scotland.

(1.) In section five of this Act the expression "Secretary for Scotland" shall be substituted for the expressions "Board of Agriculture" and "Board of Trade" respectively, occurring in that section;

(2.) References to the council of any county, borough, or district, shall be construed as references to the county council of any county, or the town council, or where there is no town council the police commissioners, of any burgh, or the commissioners of any police burgh, or the district committee of any district under the Local Government (Scotland) Act, 1889; or in any county where there is no district committee any two or more parish councils may combine;

52 & 53 Vict. c. 50.

(3.) "Arbiter" shall be substituted for "arbitrator," and that arbiter shall be deemed to be a single arbiter within the meaning of the Lands Clauses Acts, and in lieu of the provisions of the Arbitration Act, 1889, the provisions of the Lands Clauses Acts with respect to an arbitration shall apply, except the provisions of the said Acts as to the expenses of the arbitration, in lieu of which the following provision shall have effect, namely, the expenses of the arbitration and incident thereto shall be in the discretion of the arbiter, who may direct to and by whom and in what manner those expenses, or any part thereof, shall be paid, and may tax or settle the amount of expenses to be so paid, or any part thereof, and may award expenses to be paid as between agent and client;

(4.) The Lord President of the Court of Session shall be substituted for the Lord Chancellor;

(5.) The money necessary to defray expenditure, not being capital expenditure incurred by a county council in pursuance of this Act, shall be raised by a rate imposed along with but as a separate rate from the rate for maintenance of roads (herein-after referred to as "the road rate") leviable under the Roads and Bridges (Scotland) Act, 1878, upon lands and heritages within the county, or the district, or the parish, as the case may be. The money necessary to defray expenditure similarly incurred by a town council, or police commissioners, or burgh commissioners shall be raised by a rate imposed along with but as a separate rate from the police assessment or burgh general assessment, as the case may be. If the expenditure incurred is capital expenditure it shall be raised by borrowing in the manner authorised by the order, the rate chargeable for repayment of capital, including interest and expenses, being the same rate as is liable for maintenance as aforesaid;

41 & 42 Vict. c. 51.

(6.) The provisions relating to district councils shall apply to district committees or combinations of parish councils, subject to the following modifications—

(*a*) A district committee shall not be entitled to make an application under section two hereof except with the consent of the county council given at a special or statutory meeting of the council, of which one month's special notice, setting forth the purpose of the meeting, shall have been sent to each councillor,

(*b*) A resolution to give such consent shall not be passed by the council unless two-thirds of the councillors present and voting at the special or statutory meeting concur in the resolution,

(*c*) Nothing in this Act shall authorise a district committee to raise money by rate or loan, but any money necessary to defray expenditure, not being capital expenditure incurred by it in pursuance of this Act, shall be raised by the county council by a rate imposed along with but as a separate rate from the road rate; and any money necessary to defray capital expenditure shall be raised by the county council by borrowing in the manner authorised by the order, as in section sixteen hereof mentioned;

(7.) The expression "Clauses Acts" shall mean the Lands Clauses Acts the Railway Clauses Consolidation (Scotland) Act, 1845, the Companies Clauses Consolidation (Scottand) Act, 1845, the Companies Clauses Act, 1863, the Railways Clauses Act, 1863, and the Companies Clauses Act, 1869;

(8.) References to the Local Government Act, 1888, and the Local Government Act, 1894, shall be construed as references to the Local Government (Scotland) Act, 1889, and the Local Government (Scotland) Act, 1894;

52 & 53 Vict. c. 50.
57 & 58 Vict. c. 58.

(9.) In order to carry out in Scotland the provisions contained in sub-section (1) (*c*) of section five of this Act, it shall be the duty of the assessor of railways and canals, as regards any parish to which the said sub-section (1) (*c*) applies, to enter on his valuation roll either the annual value of the light railway within such parish ascertained in terms of the Valuation of Lands (Scotland) Acts, or the annual value at which the land occupied by or for the purposes of the light railway would have been assessed if it had remained in the condition in which it was immediately before it was acquired for the purposes of the railway, whichever is less;

(10.) Where a light railway constructed under the powers of this Act is owned or leased by an existing railway company, such light railway shall not be valued by the said assessor as part of the general undertaking of the railway company, but shall be valued as a separate undertaking.

27. This Act shall not extend to Ireland.

Extent of Act.

SCHEDULES.

Section 3

FIRST SCHEDULE.

Mode of Passing Special Resolutions.

1. The resolution approving of the intention to make the application must be passed at a meeting of the council.

2. The resolution shall not be passed unless a month's previous notice of the resolution has been given in manner in which notices of meetings of the council are usually given.

3. The resolution shall not be passed unless two-thirds of the members of the council present and voting concur in the resolution.

Section 12.

SECOND SCHEDULE.

Enactments Relating to Safety, &c.

[These all relate to Acts affecting Railways.]

THIRD SCHEDULE.

[These are regulations as to the appointment and powers of Joint Committees.]

APPENDIX V.

Extracts from Rules made by the Board of Trade in September, 1896, and modified in October, 1898, with respect to applications to the Light Railway Commissioners under the Light Railways Act, 1896.*

Notice of Proposed Application.

Notice by advertisement.

1. Notice of intention to apply to the Light Railway Commissioners for an Order authorising a light railway, or for an amending Order (hereinafter referred to as "the notice"), must be published by advertisement in each of two consecutive weeks in the month of May or of November, in at least one local newspaper circulating in the area or part of the area through which it is proposed to make the railway. Copies of such newspaper containing these advertisements must be sent when published to the Light Railway Commissioners and to the Board of Trade.

Contents of notice.

2. The notice must, in the case of a new railway, describe generally the line of the railway and its termini, the lands proposed to be taken (stating the quantity and the purpose for which it is proposed to take them), and the proposed gauge and motive power of the railway, and in the case of an application for an Amending Order (so far as the amendment applied for does not relate to the power to make a new railway) the nature of the proposed amendment. The notice must be subscribed with the name of the person, company, or council responsible for the publication of the notice (hereinafter referred to as "the promoters"); and must name a place where a plan of the proposed works and of the lands to be taken and a book of reference to the plan and a section of the proposed works will be deposited for inspection on or before the last day of the month in which the notice is advertised, and where on or before the same day copies of the draft Order can be obtained on payment of not exceeding one shilling per copy.

The notice must state that in accordance with these Rules objections should be made in writing to the Light Railway Commissioners, and a copy sent to the promoters.

"Gazette" advertisement.

3. A short advertisement of the intention to apply to the Light Railway Commissioners for an Order authorising a light railway or for an amending Order must also be published in the "London" or "Edinburgh Gazette," as the case may be, during the month in which the notice is advertised.

The advertisement must state the names of the promoters and their solicitors or agents, and in the case of a new railway, the termini of the railway and the names of any counties or parishes through which the railway is to run, and in the case of an amending Order (so far as the amendment applied for does not relate to power to make a new railway), as shortly as possible the nature of the amendment.

Plans, Book of Reference and Sections.

Plans.

10. Every plan must be drawn to a scale of not less than four inches to the mile, and must describe the lands intended to be taken, and the line or situation of the whole of the railway (no alternative line or work being in any case permitted), and the lands in or through which it is to be made, or through which any communication to or from the railway shall be made.

As to limits of deviation.

11. Where it is the intention of the promoters to apply for powers to make any lateral deviation from the line of the proposed railway, the limits of such deviation shall be defined on the plan, and all lands included within such limits shall be marked thereon.

Buildings, &c. on enlarged scale

12. Unless the whole of such plan shall be upon a scale of not less than a quarter of an inch to every one hundred feet, an enlarged plan shall be added of any building, yard, courtyard, or land within the curtilage of any building, or of any ground cultivated as a garden, either in the line of the proposed work, or included within the limits of the said deviation, on a scale not less than a quarter of an inch to every one hundred feet.

Distances to be marked.

13. The distances from one of the termini must be shown in miles and furlongs on the plan, and a memorandum of the radius of every curve not exceeding one mile in length, shall be noted on the plan in furlongs and chains.

Tunnelling to be marked.

14. Where tunnelling as a substitute for open cutting is intended, the same shall be marked by a dotted line on the plan, and no work shall be shown as tunnelling in the making of which it will be necessary to cut through or remove the surface soil.

Diversion of roads, &c.

15. If it be intended to divert, widen or narrow any public carriage road, navigable river, canal, or railway, the course of such diversion and the extent of such widening or narrowing shall be marked on the plan.

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*The full text of these Rules can be obtained through a bookseller: price 2½d.

Case of junctions with other lines.

16. When a railway is intended to form a junction with an existing or authorised line of railway, the course of such existing or authorised line of railway shall be shown on the deposited plan for a distance of 800 yards on either side of the proposed junction on the same scale as the scale of the general plan.

Case of rails along road.

17. If it be intended to lay any part of the railway along a road or street, the plan shall show at what distance from an imaginary line drawn along the centre of such road or street it is proposed to lay the rails ; and the widths of such road or street shall at all material points be clearly marked in figures on the plan.

Book of reference.

18. The book of reference shall contain the names of the owners or reputed owners, lessees or reputed lessees, and occupiers of all lands and houses in the line of the proposed railway or within the limits of deviation as defined on the plan, and shall describe such lands and houses respectively.

The book of reference shall also contain the name of the road authority of any road or street along which it is proposed to lay any part of the railway.

Scale of sections.

19. The section shall be drawn to the same horizontal scale as the plan, and to a vertical scale of not less than one inch to every one hundred feet, and shall show the surface of the ground marked on the plan, the intended level of the proposed railway, the height of every embankment and the depth of every cutting, and a datum horizontal line, which shall be the same throughout the whole length of the railway or any branch thereof respectively, and shall be referred to some fixed point (stated in writing on the section) near one of the termini of the railway.

In every section the line of the railway marked thereon shall correspond with the upper surface of the rails.

Vertical measures to be marked at change of gradient.

20. Distances on the datum line shall be marked in miles and furlongs, to correspond with those on the plan ; a vertical measure from the datum line to the line of the railway shall be marked in feet and inches, or decimal parts of a foot, at the commencement and termination of the railway, and at each change of the gradient or inclination thereof ; and the proportion or rate of inclination between every two consecutive vertical measures shall also be marked.

Height of railway over or depth under surface of roads, &c. to be marked.

21. Wherever the line of the railway is intended to cross any public carriage road, navigable river, canal, or railway, the height of the railway over or depth under the surface thereof, and the height and span of every arch of all bridges and viaducts by which the railway will be carried over the same, shall be marked in figures at every crossing thereof, and where the railway will be carried across any such public carriage road or railway, on the level thereof, such crossing shall be so described on the section, and it shall also be stated if such level will be unaltered.

Cross sections in certain cases.

22. If any alteration be intended in the water level of any canal, or in the level or rate of inclination of any public carriage road or railway which will be crossed by the railway, then the same shall be stated on the section, and each alteration shall be numbered ; and cross sections in reference to the numbers, on a horizontal scale of not less than one inch to every three hundred and thirty feet, and on a vertical scale of not less than one inch to every forty feet shall be added which shall show the present surface of such road, canal, or railway, and the intended surface thereof, when altered ; and the greatest of the present and intended rates of inclination of the portion of such road or railway intended to be altered shall also be marked in figures thereon, and where any public carriage road is crossed on the level, a cross section of such road shall also be added ; and all such cross sections shall extend for two hundred yards on each side of the centre line of the railway.

Embankments and cuttings.

23. Wherever the extreme height of an embankment, or the extreme depth of any cutting, shall exceed five feet, the extreme height over or depth under the surface of the ground shall be marked in figures on the section ; and if any bridge or viaduct of more than three arches shall intervene in any embankment, or if any tunnel shall intervene in any cutting, the extreme height or depth shall be marked in figures on each of the parts into which such embankment or cutting shall be divided by such bridge, viaduct, or tunnel.

Tunnelling and viaduct to be marked.

24. Where tunnelling, as a substitute for open cutting, or a viaduct as a substitute for solid embankment, is intended, the same shall be marked on the section, and no work shall be shown as tunnelling in the making of which it will be necessary to cut through or remove the surface soil.

In case of junctions gradient of existing line to be shown on section.

25. When a railway is intended to form a junction with an existing or authorised line of railway, the gradient of such existing or authorised line of railway shall be shown on the deposited section, and in connexion therewith, and on the same scale as the general section, for a distance of 800 yards on either side of the point of junction.

Notices to Owners, Lessees, and Others.

Service of notices on landowners and others.

26. In the month in which the notice is advertised the promoters must serve a notice on the owners, or reputed owners, lessees, or reputed lessees, and occupiers of all lands intended to be taken or being within the limits, of deviation shown on the deposited plan, describing in each case the particular lands intended to be taken or being within such limits, and inquiring whether the person so served assents or dissents to the taking of such lands, and requesting him to state any objections he may have to such lands being taken.

Every such notice shall be as nearly as may be in the form set out in the schedule to these Rules.

Notice to owners of railway, &c.

27. In the month in which the notice is advertised the promoters must also serve a notice of the intended application on the owner or reputed owner, lessee, or reputed lessee, of any railway, tramway, or canal which will be crossed or otherwise interfered with by the proposed railway; and on the road authority (where other than a county, borough, district, or parish council) of any road or street along which it is proposed to lay any rails, or which will be otherwise interfered with by the proposed railway; and such notice shall state the place or places where a plan or plans of the proposed railway has or have been or will be deposited.

Notice of relinquishment of works.

28. Where an amending Order proposes to authorise the promoters to vary or to relinquish the whole or any part of a railway authorised by a former Order, the promoters must in the month in which the notice is advertised serve notice of the proposal on the owners, or reputed owners, lessees, or reputed lessees, and occupiers of the lands in which any part of the said railway is situate.

Notice of repeal of protective provisions.

29. Where an amending Order proposes to repeal or alter any provision contained in a former Order for the protection or benefit of any person, public body, or company specifically named, the promoters must in the month in which the notice is advertised serve notice of the intention to repeal or alter such provision on every such person, public body, or company.

Estimate.

Estimates.

30. An estimate of the expenses of the proposed railway (including the expense of acquiring the land and all incidental expenses) must be made and signed by the person making the same.

31. The estimate shall be in the following form or as near thereto as circumstances may permit:—

Estimate of the Proposed Light Railway.

			Whether Single or Double.	
Lines No. ...				
	miles. fgs. chs.			
Length of Line ...				
Gauge ...				
	Cubic Yards.	Price per Yard.	£ s. d.	£ s. d.
Earthworks:				
Cuttings—Rock ...				
Soft Soil ...				
Roads ...				
Total ...				
Embankments, including roads ...	Cubic Yards			
Bridges—Public Roads ...	Number			
Accommodation bridges and works ...				
Viaducts ...				
Culverts and Drains ...				
Metallings of roads and level crossings ...				
Gatekeepers' houses at level crossings ...				
Permanent way, including fencing:				
	miles. fgs. chs.	Cost per mile. £ s. d.		
	at			
Permanent way for sidings, and cost of junctions ...				
Stations ...				
Contingencies ...	Per cent.			
Land and buildings:				
	a. r. p.			
Total ...		£		

The same details for each branch, and general summary of total cost.

Application to the Commissioners.

Documents to accompany applications.

32. Every application to the Commissioners for an Order must be made in the month of May or of November, being the month in which the notice is advertised, and must be in the case of a corporate body under the seal of such body, and in any other case signed by the promoter or promoters, or if there are more than two then by any three of them, and must be accompanied by—

(*a*) three copies of the draft Order and of each of the documents required by these Rules to be deposited.

(*b*) a statement as to the proposed gauge and motive power of the railway;

(*c*) a list with their postal addresses of the owners, or reputed owners, lessees, or reputed lessees, and occupiers on whom notices have been served;

(*d*) a list of the county borough district and parish councils in or through any part of whose county district or parish any part of the railway is proposed to be made, and a statement whether or not they have intimated assent to or dissent from the proposal;

(*e*) a list of the railway, tramway, or canal companies (if any) on whom any notice has been served under these rules, and a statement whether or not they have intimated assent to or dissent from the proposal;

(*f*) a statement whether any consent of the Board of Agriculture required to any grant of land or to the acquisition of any common land proposed to be authorised by the draft Order has been obtained;

(*g*) a statement whether it is proposed that the Council of any county borough or district shall expend or advance any money, and, if so, of the nature and amount of such expenditure or advance;

(*h*) a statement whether it is proposed to apply to the Treasury for the advance of any money, and, if so, of the amount of the advance sought;

(*i*) a certificate that a fee of £50 has been paid to the Board of Trade.

Documents to accompany or follow application.

33. A statement so far as can be made whether the owners or reputed owners, lessees or reputed lessees and occupiers, on whom notices have been served in each case assent, dissent, or are neuter, must be deposited with the Commissioners on or before the last day of the month after the month in which the application was made; and a certificate, in the case of an application by an existing company, that the members of the company have assented to the application by such a resolution as is required by the Standing Orders of Parliament in the case of an application to Parliament by such company must be deposited with the Commissioners before their local inquiry is held.

[Here follow general provisions as to notices, fees, &c.]

❧

APPENDIX VI.

Extracts from a typical Order of the "Railway type" made under the Light Railways Act 1896.

DARTFORD DISTRICT LIGHT RAILWAYS ORDER 1903.

Order authorising the construction of light railways in the county of Kent from the River Thames near Greenhithe to Dartford and Eynsford with branches to Swanley Junction and to Stansted.

Preamble

WHEREAS an application was in May 1897 (hereinafter called "the application of 1897") duly made to the Light Railway Commissioners by International Communications Limited in pursuance of the Light Railways Act 1896 for an Order to authorise the construction of certain light railways including the light railways hereinafter described. Now we the Light Railway Commissioners being satisfied after local inquiry of the expediency of granting the application of 189 as amended by the application of 1899 do in pursuance of the said Act and by virtue and in exercise of the powers thereby vested in and of every other power enabling us in this behalf ORDER as follows:—

Preliminary.

Short title.

1. This Order may be cited as "The Dartford District Light Railways Order 1903" and shall come into force on the date on which it is confirmed by the Board of Trade.

2. Interpretation of words and expressions.

3. Incorporation of Acts: Parts of Companies Clauses Acts and Land Clauses Acts; Railway Consolidation Act 1845 (except sections 11 to 15, 25 to 29, 46 to 48, all inclusive, and Nos. 59, 60, 63, and 64). Also parts of Railway Clauses Act 1863, and Regulation of Railways Acts 1868 and 1889.

4. 5. 6. 7. 8. 9 Sections dealing with the incorporation and meetings of the company; qualifications and appointment of directors.

Railways Authorised.

Power to make railways.

10. Subject to the provisions of this Order the Company may make and maintain in the lines and according to the levels shown on the Plan and Section the Railways hereinafter described with all proper and sufficient rails sidings junctions turntables bridges viaducts stations approaches roads yards buildings and other works and conveniences connected therewith.

The said Railways are—

[Here follow descriptions of the several railways authorised.]

11. The railway shall be constructed on a gauge of four feet eight and a half inches and the motive power shall be steam or such other motive power as the Board of Trade may approve.

12. 13. 14. 15. 16. 17. Sections dealing with the Company's power to take lands, accept leases and easements &c.

18. For the protection of the National Telephone Co.

19. For the protection of the City of London Asylum Committee.

Works.

Period for completion of works.

20. If the railway is not completed within five years from the commencement of this Order or such extended time as the Board of Trade may approve then on the expiration of that period the powers by this Order granted to the Company for making and completing the same or otherwise in relation thereto shall cease except as to so much thereof as is then completed.

Power to deviate.

21. Subject to the provisions of this Order the Company in making the railway may deviate from the lines and levels of the railway as delineated on the Plan and Section to the following extent—

(1) The Company may deviate laterally to any extent within the limits shown on the Plan and to such extent beyond those limits with the consent of the owners and lessees of the lands on which such deviation is intended to be made and of the road authority of any public road affected by such deviation as may be approved by the Board of Trade:

(2) The Company may deviate vertically from the levels of the railway shown on the Section to any extent except that—

(*a*) Where any public road is affected by such deviation the consent of the road authority shall be requisite to any deviation exceeding in any place five feet or exceeding in a town village street or land continuously built on two feet;

(*b*) Where any public sewers gas pipes or water pipes are affected by such deviation the consent of the owners or persons having the control thereof respectively shall be requisite to any deviation exceeding the respective limits aforesaid:

Provided that the Company shall not construct any embankment of a greater height above the surface of the ground than such height thereof as shown on the Section and ten feet in addition:

(3) The Company may subject to the foregoing provisions alter the radius of any curve described on the Plan so that no such curve shall thereby be reduced to a less radius than nine chains and may further reduce the radius of any curve to such extent as the Board of Trade may approve and may alter any inclination or gradient of the railway shown on the Section so that no such inclination or gradient thereby increased shall without the consent of the Board of Trade be steeper than one foot in fifty feet.

Inclinations of roads.

22. In altering any road for the purpose of constructing a bridge to carry the railway over the road or the road over the railway or for the purpose of carrying the railway across the road on the level the Company may make the same of any inclination not steeper than the inclination shown in connection therewith on the section and if no inclination be so prescribed then of such inclination in each case as may be not steeper than that prescribed for a road of the same description by the Railways Clauses Consolidation Act 1845.

23. Regulating the height and span of bridges over certain roads.

24. Regulating the bridge over the railroad belonging to the Land and Pier Company.

25. Regulating the widths of bridges carrying certain roads and footways over the railway.

As to crossing roads on level and gates.

26.—(1) Except as in this Order otherwise provided the Company may in the construction of the railway carry the same with a single line only whilst the railway shall consist of a single line and afterwards with a double line only across and on the level of any public road bridleway or footway shown on the Plan.

(2) The Company shall erect and unless so far as regards the places referred to in paragraphs (B) and (C) of this subsection otherwise permitted by the Board of Trade in writing maintain at all times gates across the railway on each side of the road—

(A) At the level crossing of the public roads respectively numbered on the Plan — in the parish of — and in the parish of — and — in the parish of —, etc.

(B) At any level crossing of a public road at which the Company determine so to erect and maintain gates; and

(C) At any level crossing of a public road at which the Board of Trade require the Company in accordance with this section so to erect and maintain gates.

(3) The Board of Trade may if at any time after the completion and opening of the railway it appears to them necessary for the public safety or for preventing cattle or horses from entering upon the railway require the Company to erect and unless otherwise permitted by the said Board in writing maintain at all times gates across the railway at each side of the road at any level crossing of a public road.

(4) Where gates are erected and maintained in accordance with this section the following provisions shall apply:—

(A) The Company shall unless otherwise permitted by the Board of Trade in writing employ a proper person to open and close such gates on either side of the level crossing:

(B) Such gates shall be kept constantly closed across the railway except during the time when engines carriages or trucks passing along the railway shall have occasion to cross the road and shall be of such dimensions and so constructed as when closed across the railway to fence in the railway and prevent cattle or horses passing along the road from entering upon the railway:

(C) The drivers or conductors of any engines carriages or trucks passing along the railway or other the person whose office or duty it may be to open or close the said gates shall cause the same to be closed as soon as such engines carriages or trucks shall have passed through the same.

Level crossings without gates.

27. With respect to every level crossing of a public road other than a level crossing where gates are erected and maintained in accordance with the foregoing provisions of this Order the following provisions shall apply (that is to say):—

(A) Cattle-guards or other suitable contrivances shall be erected or constructed at each side of the road, and so maintained and kept as to prevent cattle or horses passing along the road from entering upon the railway:

(B) At each of two points one three hundred yards along the railway in one direction from the level crossing and the other three hundred yards along the railway in the other direction from the level crossing there shall be erected and maintained a white post standing five feet above ground and bearing upon it and so as to be plainly legible by the driver of an engine approaching the level crossing a figure indicating the number of miles an hour which is fixed under the provisions of this Order as the maximum rate of speed of a train or engine approaching and within a distance of three hundred yards from the level crossing:

(c) At each of two points one fifty yards or thereabouts along the road in one direction from the point of crossing and the other fifty yards or thereabouts along the road in the other direction from the point of crossing there shall be erected and maintained by the Company a notice board cautioning the public to beware of the trains.

28. Regulating the diversion of certain footpaths. In each case the new footpath to be open for public use before the old one is stopped up.

Repair of roads and bridges.

29. Where in the exercise of the powers by this Order conferred the Company raise sink break up or otherwise interfere with any public road for the purpose of constructing the railway across the road on the level or for carrying the road over or under the railway the Company shall make good all damage done by them to the road and properly restore the road and shall for a period of twelve months from the date of such restoration properly maintain and repair the road so interfered with From and after the expiration of that period the road shall be maintained and repaired by and at the expense of the same parties in the same manner and to the same extent as other roads of the same nature within the parishes in which the road will be situate are liable to be maintained and repaired But the Company shall be and continue to be liable to maintain and repair the structure of any bridge (including the fences thereof and of the immediate approaches thereto) by which the railway shall be carried over any such road or any such road shall be carried over the railway and also so much of the road at any level crossing as lies between the rails of the railway and for a width of seven feet outside the rails on each side of the railway.

30.
31. Disputes between company and road authorities as to repair or other works in connection with roads to be determined by arbitration.

32. For the protection of certain railway companies. Light railway to make junctions with sidings and not with running lines. Particulars as to plans of works affecting these companies, inspection, signalling, damage, costs, &c.

33.
34.
35. For the protection of Sewers Commissioners, Drainage Board and Kent Water Company.

36.
37.
38.
39. For the protection of certain property owners, and power for the company to make agreements.

Opening of railway.

40.—(1) No portion of the railway shall be opened for the public conveyance of passengers until one month after notice in writing of the intention of opening it has been given by the Company to the Board of Trade and until ten days after notice in writing has been given by the Company to the Board of Trade of the time when it will be in the opinion of the Company sufficiently completed for the safe conveyance of passengers and ready for inspection.

(2) If any portion of the railway is so opened by the Company without such notice the Company shall forfeit to His Majesty the sum of twenty pounds for every day during which it continues open until the notices have been duly given and shall have expired.

(3) If the officer appointed by the Board of Trade to inspect any portion of the railway after inspection reports in writing (accompanied by a statement of his reasons for the report) to the Board of Trade that in his opinion the opening of the railway would be attended with danger to the public using it either by reason of the railway not being constructed or equipped in accordance with the provisions of this Order or by reason of some defect or default in respect of any matters not expressly prescribed in this Order the Board of Trade may order the Company to postpone the opening until the Board shall have been satisfied that all requisitions made by the inspecting officer upon his inspection as being necessary for compliance with the said provisions or for the safety of the public have been complied with or that the railway can otherwise be opened with safety to the public.

(4) If any portion of the railway is opened by the Company contrary to any such order of the Board of Trade the Company shall forfeit to His Majesty the sum of twenty pounds for every day during which it continues open contrary to that order.

(5) No such order of the Board of Trade shall be binding on the Company unless a copy of the report of the officer on which the order shall be founded is delivered to the Company with the order.

(6) This section shall extend to the opening at any time after the original inspection of the railway on behalf of the Board of Trade of any additional line of railway deviation line station junction with a line of railway carrying passengers or level crossing of a public road which forms a portion of or is directly connected with the railway but the Board of Trade may with respect to any such additional line of railway deviation line station junction with a line of railway carrying passengers or level crossing of a public road upon the application of the Company dispense with the notice of opening required to be given thereunder.

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42.
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44.
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47. } As to construction and lighting of pier, and protection of interests of Conservators of river Thames.

Provisions as to Working.

Restrictions of weight on rails and of speed.

48.—(1) The Company shall not without the previous consent in writing of the Board of Trade use upon the railway any carriage or truck bringing a greater weight than fourteen tons upon the rails by any one pair of wheels.

(2) The Company shall not run any train or engine upon the railway at a rate of speed exceeding at any time twenty-five miles an hour or exceeding twenty miles an hour when such train or engine is passing over any gradient steeper than one foot in fifty feet or exceeding ten miles an hour when such train or engine is passing over any curve the radius of which is less than nine chains.

(3) The rate of speed of a train or engine approaching within the distance of three hundred yards from a level crossing over a public road where no gates are erected and maintained across the railway shall not exceed ten miles an hour but the Board of Trade may fix a lower maximum speed in the case of any such level crossing if the view of the railway from the road near the crossing is at any point or for any distance so obstructed as in their opinion to render the higher maximum speed unsafe for the public using the road.

49. Trains not to stand unnecessarily across level crossings.

50.
51. } As to working agreements with certain railway companies and preserving rights of Postmaster-General under Telegraph Act 1878.

52.
53. } Provisions as to motive power and use of electric power. These are the same as secs. 21 and 26 of the Heywood Order, with the following additional sub-section to sec. 26.

(7) When any Department of His Majesty's Government represents to the Board of Trade that the use of electrical power under this Order injuriously affects or is likely to injuriously affect any instruments or apparatus whether electrical or not used in any observatory or laboratory belonging to or under the control of that Department the Board of Trade after such inspection or inquiry as they may think proper may by their regulations require the Company to use such reasonable and proper precautions including insulated returns as the Board of Trade may deem necessary for the prevention of such injurious affection For the purposes of this subsection any inspector of the Board of Trade may during his inspection of the Company's works and apparatus be accompanied by any person or persons appointed in that behalf by the Government Department concerned and the Company shall give all due facilities for the inspection Provided that in the case of any observatory or laboratory established after the commencement of this Order or of any instruments or apparatus hereafter used in any existing observatory or laboratory which may be of greater delicacy than those used therein at the commencement of this Order the Board of Trade shall consider to what extent if any it is expedient in the interests of the public that the powers of this subsection should be exercised regard being had to the site of the observatory or laboratory or the purposes of the instruments or apparatus as the case may be:

(8) In this section the expression "the Company" includes any person owning working or running carriages over the railway.

54. Protection of Postmaster-General (same as sec. 27 Heywood Order).

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57.
58.
59.
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61.
62.
63.
64. } Sections relating to tolls, rates for goods, regulations as to use of pier, &c.

65.
66.
67.
68.
&c.
to
79. } Sections dealing with capital of Company and other financial matters.

80. The provisions of the First Schedule to this Order shall be observed.

81.
82.
83.
84. } Provisions as to general Acts, arbitration penalties and costs of Order.

SCHEDULES.

FIRST SCHEDULE.

Permanent Way.—The rails used shall weigh at least sixty pounds per yard.

On curves with radii of less than nine chains a check rail should be provided.

If flat-bottom rails and wooden sleepers are used—

(A) The rails at the joints shall be secured to the sleepers by fang or other through bolts or by coach-screws or by double spikes on the outside of the rail with a bearing plate; and

(B) The rails on curves with radii of less than nine chains shall be secured on the outside of the outer rail to each sleeper by a fang or other through bolt or by a coach-screw or by double spikes with a bearing plate; and

(C) The rails on curves with radii of less than nine chains shall be tied to gauge by iron or steel ties at suitable intervals or in such other manner as may be approved by the Board of Trade.

Turntables.—No turntables need be provided but no tender-engine shall be run tender foremost at a rate of speed exceeding at any time fifteen miles an hour.

Electrical Communication.—If the Board of Trade require means of electrical communication to be provided on the line the Company shall make that provision in such manner as the Board of Trade direct.

Signals.—At stations where under the system of working for the time being in force trains may cross or pass one another there shall be a home-signal for each direction at or near the entrance points. If the home-signal cannot be seen from a distance of a quarter of a mile a distant-signal must be erected at that distance at least from the entrance points.

Home-signals and distant-signals may be worked from the station by wires or otherwise.

Every signal-arm shall be so weighted as to fly to and remain at danger on the breaking at any point of the connection between the arm and the lever working it.

Precautions shall be taken to the satisfaction of the Board of Trade to ensure that no signals can be lowered unless the points are in the proper position and that two conflicting signals cannot be lowered simultaneously.

Platforms, &c.—Platforms shall be provided to the satisfaction of the Board of Trade unless all carriages in use on the railway for the conveyance of passengers are constructed with proper and convenient means of access to and from the same from and to the level of the ground on the outside of the rail.

There shall be no obligation on the Company to provide shelter or conveniences at any station or stopping place.

This Order made by the Light Railway Commissioners and modified by the Board of Trade is hereby confirmed in pursuance of the provisions of Section 10 of the Light Railways Act 1896.

Given under the Seal of the Board of Trade this thirtieth day of September One thousand nine hundred and three.

G. W. BALFOUR,
President.
HERBERT JEKYLL,
Assistant Secretary.

APPENDIX VII.

Extracts from a typical Order of the "tramway type" made under the Light Railways Act 1896.

GLOUCESTER CORPORATION LIGHT RAILWAYS ORDER 1903.

Order authorising the construction of Light Railways in the City of Gloucester.

Preamble. WHEREAS an application was in November 1899 (hereinafter referred to as "the application of 1899") duly made to the Light Railway Commissioners by the City of Gloucester Tramways Company Limited in pursuance of the Light Railways Act 1896 for an Order to authorise the construction of light railways including Railways (No. 1) (No. 1A) (No. 2) (No. 3) and (No. 4) hereinafter described AND WHEREAS by the Gloucester Tramways Order 1878 and the City of Gloucester Tramways Order 1895 the said Company were authorised to construct and maintain certain tramways AND WHEREAS the light railways by this Order authorised will be partly constructed upon the roads now occupied by the said tramways and will render necessary the removal of the same AND WHEREAS the Mayor Aldermen and Citizens of the City of Gloucester in the County of the City of Gloucester (hereinafter called "the Corporation") have in pursuance of Section 44 of the Tramways Act 1870 and with the consent of the Board of Trade agreed to purchase the said tramways and it has also been agreed between the said Company and the Corporation that this Order shall be granted to the Corporation AND WHEREAS an application was in May 1902 (hereinafter referred to as "the application of 1902") duly made to the Light Railway Commissioners by the Corporation in pursuance of the Light Railways Act 1896 for an Order to authorise the Corporation to construct light railways including the light railways hereinafter described as Railways (No. 1) (No. 1A) (No. 2) (No. 3) (No. 4) (No. 5) and (No. 6) AND WHEREAS the Corporation for the purpose of affording a more convenient termination of the line have applied for powers to construct the extensions hereinafter described as Railways (No. 2A) and (No. 2B) and have given public notice of the same by advertisement and by deposit of plans AND WHEREAS the Order authorises the Corporation to contract for the working running over and user of certain light railways outside the area of the City and in accordance with section 3 of the said Act it has been proved to the satisfaction of the Board of Trade that such working running over or user of the said light railways by the Corporation is expedient in the interests of the said City and the Board are also of opinion that the expenditure of the Corporation is so limited by this Order as not to exceed such amount as will bear due proportion to the benefit which may be expected to accrue to the said City from the working running over or user of the said light railways NOW we the Light Railway Commissioners being satisfied after local inquiry of the expediency of granting the said application including the said extensions do in pursuance of the Light Railways Act 1896 and by virtue and in exercise of the powers thereby vested in and of every other power enabling us in this behalf ORDER as follows:

Preliminary.

Short title. 1. This Order may be cited as "The Gloucester Corporation Light Railways Order 1903" and shall come into force on the date on which it is confirmed by the Board of Trade.

Interpretation. 2. Words and expressions to which by the Light Railways Act 1896 or by any enactment incorporated with this Order meanings are assigned have in this Order (unless the context otherwise requires) the same respective meanings and in this Order—

The expression "the Corporation" means the Mayor Aldermen and Citizens of the City of Gloucester in the County of the City of Gloucester and the expression "the City" means the said City of Gloucester;

The expression "the principal Act" means the Light Railways Act, 1896;

The expression "the railway" means the railways and works by this Order authorised or (as the case may be) any part thereof and the expression "the undertaking" means the undertaking by this Order authorised;

The expressions "the Plans" "the Sections" and "the Book of Reference" mean respectively the plans sections and book of reference deposited in respect of the application of 1899 and of the application of 1902 and of the extensions in the Preamble to this

Order referred to with the Board of Trade and signed by an assistant-secretary of the Board of Trade;

The expression "mechanical power" includes steam electric and every other motive power not being animal power and the word engine includes motor;

The expression "local authority" means the council of any borough or urban district or rural district;

The expression "road" means any carriage way being a public highway and the carriage way of any bridge forming part of or leading to the same;

The expression "road authority" means any county council local authority commissioners trustees or other body or persons who are charged with the duty of maintaining or repairing any road;

The expression "metalled" means so paved or made in any way as to form a road for vehicular traffic and the expression "unmetalled" shall be construed accordingly;

The expression "special resolution" means a resolution passed by a majority of not less than two-thirds of the members present and voting at a meeting of a local authority of which meeting at least one month's previous notice specifying the resolution to be proposed at such meeting has been given in the manner in which notice of the meetings of such local authority is usually given;

The Interpretation Act 1889 applies for the purposes of this Order as if this Order were an Act of Parliament.

3. Incorporation of parts of the Lands Clauses Acts, and of parts of general Acts relating to railways. Certain parts of Railway Regulations Acts 1840 1868 and 1871 not to apply.

Railways Authorised.

Power to make railways.

4. Subject to the provisions of this Order the Corporation may make form lay down and maintain the Railways hereinafter described in the lines and according to the levels and within the limits of deviation shown on the Plans and Sections with all proper rail plates works and conveniences connected therewith. The said Railways are—

[Here follows description of the several railways authorised.]

Provided that before or when constructing the said Railways on any road on which the existing tramways are situate the Corporation shall take up and remove the same.

Provided further that where the Railway crosses existing railways on the level the Corporation shall provide and maintain such safety appliances and work the railway in accordance with such conditions as the Board of Trade may from time to time prescribe and that on non-compliance with this provision the Corporation shall be subject to a penalty of five pounds for every day on which such non-compliance continues.

Power to make crossings, &c.

5. (1) In addition to and in connection with the Railways hereinbefore described the Corporation may subject to the provisions of this Order and in respect of any part of the railway within the district of any local authority other than the Corporation with the consent of the local authority or on any road of which the Corporation are not the road authority with the consent of the road authority make maintain alter and remove such crossings passing places sidings junctions and other works as they find necessary or convenient for the efficient working of the railway or for providing access to any stables engine-houses power-houses carriage-houses sheds or works of the Corporation: Provided that if before commencing to make alter or remove any such work as aforesaid in any road in the district of any such local authority or under any such road authority the Corporation deliver to the authority a plan showing the position of the work proposed to be made altered or removed as the case may be and the authority do not within twenty-eight days give notice to the Corporation of any objection such authority shall be taken to have consented to the making alteration or removal of such work as shown by the said plan.

(2) Before commencing to make alter or remove any such work as aforesaid the Corporation shall prepare and send to the Board of Trade a plan showing the position of the work proposed to be made altered or removed as the case may be and shall not make alter or remove the work except with the approval of the Board of Trade.

(3) The consent of the local or road authority under this section shall not be unreasonably withheld and if any difference arises as to whether such consent is unreasonably withheld that difference shall be referred to arbitration under this Order.

Power to generate electricity.

6. (1) For the purposes of working the railway the Corporation may supply electrical energy from any generating station belonging to them and may erect construct maintain and use dynamos and other electrical apparatus steam engines works and buildings and may use for the purposes aforesaid or any of them any land appropriated by them to that use or acquired by them by agreement under the powers of this Order but nothing in this section shall exempt the Corporation from any indictment action or other proceeding for nuisance in the event of any nuisance being caused or permitted by them on any land so appropriated or acquired.

(2) The Corporation may enter into and carry into effect vary or rescind agreements with respect to the supply to the Corporation of electric power for the purposes of this Order by any person duly authorised to give such supply.

Power to lay down conductors &c.

7. Subject to the provisions of this Order the Corporation may erect lay down and maintain on in under or over any road or the footpath of any road such posts conductors wires tubes mains plates boxes and apparatus as may be necessary or convenient either for the working of the railway or for forming connections with any generating station and the powers and obligations of the

Corporation under this Order with respect to the opening or breaking up of any road shall so far as they are applicable, apply with respect to such footpaths: Provided that the powers of this section shall not be exercised with respect to any road or footpath of which the Corporation are not the road authority except with the consent (which shall not be unreasonably withheld) of the road authority and if any difference arises as to whether such consent is unreasonably withheld that difference shall be referred to arbitration under this Order.

Gauge of railway.

8. The railway shall be constructed on a gauge of three feet six inches or such other gauge as may from time to time be determined by the Corporation with the consent of the Board of Trade.

Right of user only of road.

9. Notwithstanding anything in this Order contained the Corporation shall not acquire or be deemed to acquire any right other than that of user of any road on which they lay the railway or of any bridge culvert or other work upon which such road is carried.

Reservation of right of public to use roads.

10. Nothing in this Order or any bye-law made under this Order shall take away or abridge the right of the public to pass along or across every part of any road on which the railway is laid except as hereinafter expressly provided with reference to carriages not having flange-wheels or wheels suitable only to run on the rails of the railway.

Reservation of powers to widen roads, &c.

11. Nothing in this Order shall take away or affect any power of any road authority or of the owners commissioners undertakers or lessees of any railway tramway inland navigation or bridge to widen alter divert repair maintain or improve any road railway tramway inland navigation or bridge or to rebuild any bridge: Provided that such powers shall not be exercised so as to interfere with or affect the railway or the traffic thereon further or otherwise than may be necessary and that nothing in this Order shall entitle the Corporation to compensation for any loss or damage sustained by them by reason of the reasonable exercise of such powers as aforesaid.

Reservation of rights of owners &c. of mines.

12. Nothing in this Order shall limit or interfere with the rights of any owner lessee or occupier of any mines or minerals to work the same nor shall any such owner lessee or occupier be liable to make good or pay compensation for any damage which may be occasioned to the railway by the working in the usual and ordinary course of mines or minerals.

Lands.

Appropriation and acquisition by agreement of lands.

13. The Corporation may—

(A) subject to the sanction of the Local Government Board and under such conditions as the Board may prescribe appropriate and use for the purposes of the undertaking but subject to the provisions (if any) under which such lands were respectively acquired any lands not dedicated to public use vested in them being part of their corporate estates; and

(B) by agreement purchase and acquire for the purposes of the undertaking such lands as they may require and may sell or dispose of any such lands not required for such purposes:

Provided that they shall not at any time hold in pursuance of this section more than five acres of land and that nothing in this Order shall exempt the Corporation from any indictment action or other proceeding for nuisance in the event of any nuisance being caused or permitted by them upon any land appropriated or acquired by them under this section.

Persons under disability may grant easements, &c.

14. Persons empowered by the Lands Clauses Acts to sell and convey or release lands may if they think fit subject to the provisions of those Acts and of this Order grant to the Corporation for the purposes of this Order any easement right or privilege (not being an easement right or privilege of water in which persons other than the grantors have an interest) in over or affecting any such lands and the provisions of the said Acts with respect to lands and rent charges so far as the same are applicable in this behalf shall extend and apply to such easements rights and privileges respectively.

Restrictions on taking houses of labouring class.

15. (1) The Corporation shall not under the powers of this Order purchase or acquire in any city borough or other urban district nor elsewhere than in an urban district in any parish ten or more houses which on the fifteenth day of December last were occupied wholly or partially by persons belonging to the labouring class as tenants or lodgers nor except with the consent of the Local Government Board ten or more houses which were not on the said fifteenth day of December but at any time between that date and the time at which such purchase or acquisition takes place or is intended to take place may have been or be so occupied.

(2) If the Corporation purchase or acquire any house in contravention of the foregoing provisions they shall be liable to a penalty of five hundred pounds in respect of every such house which penalty shall be recoverable by the Local Government Board by action in the High Court and any sum so recovered shall be carried to and form part of the Consolidated Fund of the United Kingdom: Provided that the Court may if it think fit reduce such penalty.

(3) For the purposes of this section the expression "labouring class" means mechanics artisans labourers and others working for wages hawkers costermongers persons not working for wages but working at some trade or handicraft without employing others except members of their own family and persons other than domestic servants whose income does not exceed an average of thirty shillings a week and the families of any of such persons who may be residing with them and the expression "house" means any house or part of a house occupied as a separate dwelling.

Works.

Period for completion of works.

16. Subject to the provisions of this Order unless the Corporation complete Railways (No. 1) and (No. 1*a*) the part of Railway (No. 2) to the south-east of the main entrance to St. Nicholas Church the part of Railway (No. 3) between its commencement and its junction with Railway (No. 5) and Railways (No. 5) and (No. 6) within three years and the remainder of the railway within five years from the commencement of this Order the powers of the Corporation under this Order shall cease: Provided that the Board of Trade may allow an extension of time as regards any such part of the railway or may direct that the powers of the Corporation shall cease under this section as regards some part of the railway only and not as regards the whole subject in either case to such conditions (if any) as they may impose: Provided also that the Corporation shall construct the part of Railway (No. 1) from the terminus of the existing tramways up to the City boundary in London Road concurrently with the construction of any light railway or tramway capable of being worked in connection therewith from the termination of Railway (No. 1) at the City boundary to Hucclecote in the County of Gloucester but shall not be obliged to construct the same except concurrently therewith.

Power to break up roads &c.

17. For the purpose of making laying down maintaining and renewing or altering the railway the Corporation may exercise in respect of any road street or other highway any powers vested in them as the authority having the control of such road street or highway and so far as such powers do not extend they may open and break up any road subject to the following regulations:—

(1) They shall seven days at least before the commencement of the work give to the road authority notice specifying the time at which they will begin the work and the portion of road proposed to be opened or broken up;

(2) They shall not open or break up or alter the level of any road except under the superintendence and to the reasonable satisfaction of the road authority unless that authority refuse or neglect to give such superintendence at the time specified in the notice or discontinue the same during the work;

(3) They shall pay all reasonable expenses to which the road authority are put on account of such superintendence;

(4) They shall not without the consent of the road authority open or break up at any time a greater length than one hundred yards of any road which does not exceed a quarter of a mile in length and in the case of any road exceeding a quarter of a mile in length the Corporation shall not without a like consent leave a less interval than a quarter of a mile between any two places at which they may open or break up the road and they shall not without the like consent open or break up at any one time at any such place a greater length than one hundred yards;

(5) Where the road on which the railway is proposed to be laid is crossed by any railway or tramway on the level any work which the Corporation are empowered to construct and which affects or in anywise interferes with such railway or tramway or the traffic thereon shall be constructed and maintained to the reasonable satisfaction of the owner or lessee of such railway or tramway and under his superintendence (at the expense of the Corporation) unless after notice to be given by the Corporation seven days at least before the commencement of such work such superintendence is refused or withheld;

(6) If any difference arises under this section as to the reasonable satisfaction of the road authority or of the owner or lessee of a railway or tramway or as to any expenses to be paid by the Corporation that difference shall be referred to arbitration under this Order.

18. Construction to be approved by Board of Trade. [Same as section 11 of Heywood Tramway Order.]

Completion of works and reinstatement of road.

19. When the Corporation have opened or broken up any metalled portion of any road of which they are not the road authority they shall be under the following further obligations; (namely)—

(1) They shall with all practical speed and in all cases within four weeks at the most (unless the road authority otherwise consent in writing) complete the work on account of which they opened and broke up the road and (subject to the making maintenance or renewal of the railway) fill in the ground and make good the surface and to the reasonable satisfaction of the road authority restore the portion of the road to as good condition as that in which it was before it was opened or broken up and clear away all surplus paving metalling or other material or rubbish occasioned thereby.

(2) They shall in the meantime cause the place where the road is opened or broken up to be fenced and watched and to be properly lighted at night.

(3) They shall pay all reasonable expenses of the repair of the road for six months after the same is restored so far as those expenses are increased by the opening or breaking up.

If any difference arises under this section as to the reasonable satisfaction of the road authority or as to the reasonable expenses to be paid by the Corporation that difference shall be referred to arbitration under this Order.

20. Application of materials excavated from roads. [Same as section 19 of Heywood Order.]

Repair of metalled portion of road where railway is laid.

21. The following provisions shall apply with respect to the metalled portion of any road whereon the railway is laid; (that is to say)—

(1) The Corporation shall at their own expense at all times make repair maintain and keep in good condition and in the case of any road of which the Corporation are not the road authority in such manner as the road authority and the Corporation may agree or may have agreed or as in case of difference between them may be determined by the Board of Trade so much of the road as lies between the rails of the railway and (where two lines of railway are laid by the Corporation in any road at a distance of not more than four feet from each other) the portion of the road between such two lines of railway and in every case so much of the road as extends eighteen inches beyond the rails of and on each side of the railway: Provided that the portion of the road repairable as aforesaid by the Corporation shall (unless and as far as it may be or may have been otherwise agreed between the Corporation and the road authority or may be otherwise required by the Board of Trade) be made repaired and maintained with similar materials to those used in each case by the road authority in maintaining and repairing the other portions of such roads in the same place except that the road authority may in all cases require the road on each side of each rail to be paved repaired and maintained with one row of setts of granite or other suitable material laid to an average width on each side of each rail of at least six inches: Provided also that where any public building school or place of public worship abuts upon any such road which is or is at any time being paved with wood by the road authority the Corporation shall if the road authority where other than the Corporation so require pave repair and maintain with wood paving so much of the portion repairable by the Corporation as aforesaid as lies opposite to and extends fifty feet beyond each end of any such public building school or place of public worship.

(2) If the Corporation abandon the undertaking or any part of the same and take up the railway from any road they shall with all convenient speed and in all cases within six weeks at the most (unless the road authority otherwise consent in writing) fill in the ground and make good the surface and to the satisfaction of the road authority where other than the Corporation restore the portion of the road upon which the railway taken up was laid to as good a condition as that in which it was before such railway was laid thereon and clear away all surplus paving metalling or other material or rubbish occasioned by such work and they shall in the meantime cause the place where the road is opened or broken up to be fenced and watched and to be properly lighted at night.

(3) If the Corporation fail to comply with the provisions of this section the road authority where other than the Corporation may if they think fit themselves at any time after seven days notice to the Corporation open and break up the road and do the works necessary for the repair and maintenance or restoration of the road to the extent in this section above-mentioned and the expense incurred by the road authority in so doing shall be repaid to them by the Corporation.

(4) Any difference (except such as is to be determined by the Board of Trade as hereinbefore provided) which arises under this section between the Corporation and the road authority shall be referred to arbitration under this Order.

As to construction of railway on road.

22. (1) Before commencing to construct any part of the railway on any road the Corporation shall prepare a plan showing where it is proposed to construct the same as a single line or as a double line or as an interlacing line or otherwise and showing the proposed position thereof in the road and if a single or interlacing line the proposed position of the passing places and shall deliver to the road authority of any road of which the Corporation are not the road authority a copy of the plan so far as it affects such road.

(2) Such plan shall be open to the inspection of the owners lessees and occupiers of any houses or other buildings abutting on the road and it shall be the duty of the Corporation within seven days after they deliver the copy as aforesaid to give public notice by advertisement or otherwise of the place where and the hours when such plan may conveniently be inspected.

(3) If the road authority have any objection to the construction of the railway in accordance with such plan they may give notice thereof in writing to the Corporation and any difference between the Corporation and the road authority shall be determined by the Board of Trade: Provided that if such authority do not give such notice to the Corporation within twenty-eight days after the delivery of the plan they shall be taken to have agreed.

(4) The Corporation shall in any event submit the plan to the Board of Trade for their approval and shall not construct the railway except in accordance with the plan as approved by the Board of Trade.

Alteration of lines after construction.

23. (1) At any time after the construction of the railway the Corporation may subject to the provisions of this Order and with the consent of the road authority (which consent shall not be unreasonably withheld) in the case of any road of which the Corporation are not the road authority alter the position of the railway in any road or may lay down in any road a double line in place of a single or interlacing line or a single line in place of a double or interlacing line or an interlacing line in place of a double or single line on any part of the railway.

(2) The Corporation shall before commencing any works under this section prepare a plan showing the position of the proposed works and the manner in which it is proposed to carry them out and shall deliver to any such road authority as aforesaid a copy of the plan so far as it affects such road and such plan shall be open to the inspection of the owners lessees and occupiers of any houses or other buildings abutting on the road and it shall be the duty of the Corporation within seven days after they deliver the copy as aforesaid to give public notice by advertisement or otherwise of the place where and the hours when such plan may conveniently be inspected.

(3) If the road authority have any objection to the proposed alterations or to such plan as aforesaid they may give notice thereof in writing to the Corporation and any difference between the Corporation and the road authority shall be determined by the Board of Trade: Provided that if such authority do not give such notice to the Corporation within twenty-eight days after the delivery of the plan they shall be taken to have agreed.

(4) The Corporation shall in any event submit the plan to the Board of Trade for their approval and shall not construct the railway except in accordance with the plan as approved by the Board of Trade.

(5) If at any time after the construction of the railway on any road such road be altered or widened by the road authority the Corporation shall at their own expense if (under the circumstances) reasonably required to do so take up and remove such railway or any part thereof and reconstruct the same in such position in the road as the road authority and the Corporation may agree or failing agreement as may be determined by the Board of Trade.

(6) Where owing to the erection after the commencement of this Order of buildings houses abut on both sides of any road on which the railway has been laid as a single line only and it appears to the road authority (other than the Corporation) that for that reason an interlacing or double line should be laid instead of a single line in the road between such houses they may (if reasonable under the circumstances so to do) require the Corporation to alter their line accordingly and the Corporation shall comply with the requisition.

(7) If the Corporation consider that any such requisition or the withholding of any such consent under this section as aforesaid is not reasonable they may appeal to the Board of Trade and the decision of that Board shall be final.

As to rails of railway.

24. (1) The rails of the railway shall be such grooved or other rails as the Board of Trade may approve.

(2) Where the railway is laid on the metalled portion of any road the rails of the railway shall be laid and maintained so that the uppermost surface thereof shall be on a level with the surface of the road: Provided that if any road authority (other than the Corporation) metal the unmetalled portion of or alter the level of any road along which the railway is laid or is authorised to be laid the Corporation shall at their own expense lay or (as the case may be) alter the rails so that the uppermost surface thereof shall be on a level with the surface of the road as metalled or altered.

25. Liability of Corporation to maintain rails, &c. [Same as section 13 of Heywood Order, except that no reference is made to Tramway Act 1870.]

Corporation and road authority may contract for repairing &c. roads.

26. The Corporation and any road authority (other than the Corporation) may enter into and carry into effect and renew or vary contracts agreements or arrangements with respect to the widening and making or maintenance and repair of the whole or any portion of any road on which the railway is laid and the proportion to be paid by either of them of the expense of such works.

As to posts standards and brackets.

27. (1) Subject to the provisions of this Order and of any regulations made under this Order by the Board of Trade the size position design and construction of all posts standards and brackets and their several attachments erected in any road or the footpath of any road under any road authority other than the Corporation shall be such as the road authority and the Corporation may agree: Provided that—

(A) subject to the approval of the Board of Trade under this section and with the consent of the owners lessees and occupiers of the houses or buildings to be utilised the Corporation may and if the road authority so require and such consent can be obtained for a reasonable consideration the Corporation shall fix to houses or other buildings instead of erecting such posts or standards for the purpose any brackets or attachments for the support of any overhead wires necessary for working the railway; and

(B) before the erection of any such posts standards brackets and attachments in any such road or footpath the Corporation shall deliver to the road authority a drawing and a description of the same and a plan showing the proposed position thereof and if the authority do not within twenty-eight days give notice to the Corporation of any objection such authority shall be taken to have agreed to the size position design and construction of such posts standards brackets and attachments as shown by the said drawing description and plan; and

(C) if any post or overhead wire becomes owing to the construction of any new road or otherwise in the opinion of any such road authority an obstruction the Corporation shall alter the position thereof in such manner as the road authority may reasonably require; and

(D) if any post is erected upon the metalled portion of any road which is not lighted from the expiration of the hour after sunset until the beginning of the hour before sunrise the Corporation shall bear the expense of providing and maintaining thereon between such hours a sufficient light for the purpose of lighting such post but not otherwise for the purpose of illumination; and

(E) the Corporation shall properly maintain and keep in good order and repair to the reasonable satisfaction of the road authority all such posts standards brackets and attachments; and

(F) if any difference arises under this sub-section between the Corporation and any authority that difference shall be determined by the Board of Trade.

(2) The local authority other than the Corporation of any district in which the railway is

situate shall upon giving not less than fourteen days' notice to the Corporation of their desire to do so have the right without payment to use any posts standards and brackets erected in the streets within their district for the support of any electric wires or lamps or any gas lamp belonging to the local authority and used for public lighting or belonging to any contractor with them for the lighting of street lamps: Provided that the said notice shall be accompanied by sufficient plans to be approved by the Corporation (such approval not being unreasonably withheld) showing the method and position in which it is proposed that such wires or lamps should be supported and that in placing maintaining or altering such wires or lamps no obstruction shall be caused to the working by the Corporation of the undertaking and no unnecessary damage shall be caused to such posts standards or brackets and that if any damage is caused thereto the local authority shall be responsible for and shall make good the same to the Corporation: Provided also that any difference arising under this sub-section between the Corporation and the local authority shall be referred to arbitration under this Order.

(3) Before commencing to fix any brackets or attachments to houses or other buildings or to erect any posts standards or brackets and before any wires or lamps are supported on any such posts standards or brackets under this section plans showing where any brackets or attachments are to be affixed to houses or other buildings and the position design and construction of the posts standards or brackets and where wires or lamps are to be supported on any such posts standards or brackets the method and position in which they are to be supported shall be sent by the Corporation to the Board of Trade and the brackets and attachments shall not be fixed to houses or other buildings nor shall the posts standards or brackets be erected nor shall wires or lamps be supported on any such posts standards or brackets except according to plans approved by the Board of Trade.

(4) The provisions of the section of this Order of which the marginal note is "Alteration of lines after construction" shall apply so far as they are applicable to any alteration by the Corporation of the said posts standards brackets and attachments in respect of the matters aforesaid: Provided that before making any such alteration which would affect any such wires or lamps as are hereinbefore referred to the Corporation shall give not less than fourteen days' notice to the person owning the same.

(5) Advertisements shall not be displayed upon any such posts standards or brackets but this provision shall not be deemed to apply to notices relating only to the working or the use of the railway.

For the protection of owners of bridges and culverts.

28. (1) The Corporation shall so construct maintain and use the railway under or upon any bridge or culvert belonging to or maintainable by any person other than the Corporation (in this section referred to as "the owner") as not injuriously to affect the same and in the event of any injury or damage being caused to any such bridge or culvert by the construction maintenance or user of the railway the Corporation shall at their own expense and to the reasonable satisfaction of the owner make good and restore the same and if in consequence of any such injury or damage it becomes or if the construction of the railway or the user thereof will render it necessary that such bridge or culvert should be rebuilt or strengthened the owner shall give to the Corporation notice accompanied by sufficient plans and specifications of the intended works and may after one month from the date of the notice (or forthwith in case of emergency) proceed with all despatch to execute all such works as may be reasonably necessary and the owner may recover from the Corporation all moneys reasonably expended by him in the execution thereof;

(2) The Corporation shall give to the owner fourteen days' notice in writing of the intention to commence any works under or upon or which may affect or interfere with the structural works of any such bridge or culvert and shall at the same time send sufficient plans sections specifications and other information to show the nature of such works and such works shall be constructed and thereafter maintained according to the plans sections and specifications and under the superintendence (if such superintendence shall be given) and to the reasonable satisfaction of the owner: Provided that the Corporation shall not commence any such works until such plans sections and specifications have been approved by the owner or in case of difference between the owner and the Corporation by an arbitrator to be appointed as hereinafter provided;

(3) Any works under this section in so far as they affect or interfere with any such bridge or culvert shall if the owner so require be executed by the owner at the reasonable expense of the Corporation. If the owner intends so to execute such works he shall give to the Corporation notice of his intention and shall commence execute and complete the said works with all reasonable despatch: Provided that unless the owner gives the said notice to the Corporation within fourteen days after receiving from the Corporation the notice hereinbefore prescribed the Corporation may in accordance with such plans sections and specifications and under such superintendence as aforesaid themselves proceed to execute the works;

(4) If any such bridge or culvert as aforesaid upon which the railway is laid is altered widened or rebuilt by the owner the owner may require the Corporation to alter the railway in such manner as the circumstances of the case may reasonably require and shall at the same time send sufficient plans specifications and other information to show the nature of the alteration required;

(5) If the owner hereafter requires to widen lengthen strengthen reconstruct alter or repair any bridge under or upon which the railway is laid or the approaches thereto or to widen or alter any railway thereunder or to lift or support any such bridge the Corporation shall afford to the owner all reasonable and proper facilities for the purpose and if the owner finds it necessary for such purpose that the working or user of any part of the railway under or upon such bridge or approaches be wholly or in part stopped or delayed or that such part of the railway be wholly

or in part taken up or removed and if the owner accordingly gives to the Corporation seven days' notice in writing (or in case of emergency such notice as may be reasonably practicable) requiring such stoppage delay taking up or removal then the working or user of such part of the railway shall be stopped or delayed or such part of the railway shall be taken up or removed as stated in such notice at the reasonable expense of the Corporation and under their superintendence (if they shall give such superintendence) but no such working or user shall be stopped or delayed for a longer period than may be necessary for effecting such purpose as aforesaid and such part of the railway shall be restored with all possible despatch and in such case the owner shall not be liable to pay compensation in respect of such stoppage delay or taking up or removal as aforesaid;

(6) If any difference arises under this section between the Corporation and the owner that difference shall be referred to arbitration under this Order.

For the protection of railway companies.

29. In addition to the provisions of the section of this Order of which the marginal note is "For the protection of owners of bridges and culverts" the following provisions for the protection in any case of any railway company (in this section respectively called and severally referred to as "the protected company") shall except so far as it may be otherwise agreed in writing between the Corporation and the protected company have effect; (that is to say)—

(1) The Corporation shall not in any manner in the execution maintenance user or repair of any of their works obstruct or interfere with the free uninterrupted and safe user of any railway or other work belonging to the protected company or any traffic thereon;

(2) The Corporation shall be responsible for and make good to the protected company all losses damages and expenses which may be occasioned to the protected company by or by reason of the execution or failure of any of the intended works or by reason of any act or omission of the Corporation or their contractors or of any person in the employ of either of them and the Corporation shall effectually indemnify the protected company from all claims and demands upon or against them by reason of such execution or failure or of any such act or omission;

(3) The Corporation shall on demand pay to the protected company the reasonable expense of the employment by the protected company during the execution or repair by the Corporation under this Order of any work affecting any bridge railway or other work belonging to the protected company of a sufficient number of inspectors watchmen and signalmen to be appointed by the protected company for preventing all interference obstruction danger and accident from any of the operations acts or defaults of the Corporation or their contractors or of any person in the employ of either of them;

(4) Any additional expense in the maintenance of any bridge level-crossing or other work occasioned to the protected company by the construction or user of the railway or by or in consequence of the widening or alteration of such bridge level-crossing or approaches or work carried out under this Order shall be borne by the Corporation;

(5) The protection afforded to the protected company by this section shall not extend to the case of any interference with the wires lines and apparatus of the protected company or the currents therein to which the section of this Order of which the marginal note is "Special provisions as to use of electric power as motive power" applies but the protected company shall not by reason of being specially protected as regards other matters under this section lose as regards any such interference any protection to which they are otherwise entitled;

(6) If in consequence of the construction of Railway (No. 5) across the High Orchard Dock Branch of the Midland Railway Company on the level that Company are required by the Board of Trade to erect any additional machinery or signals or other works the Corporation shall repay to the said Company all expenses reasonably incurred by them in complying with such requirements and also any additional expense so incurred in working and maintaining such machinery or signals or other works;

(7) If any difference arises under this section between the Corporation and the protected company that difference shall be referred to arbitration under this Order.

Protection to railway companies against breaking or falling wires.

30. (1) If having regard to the proposed position of any works by this Order authorised when considered in relation to the position of the works of any railway company at any point where the railway will be constructed over or under any railway of such railway company it becomes advisable in order to avoid danger from the breaking or falling of wires that the electric telegraphic telephonic or signal wires or apparatus of such railway company should be altered the railway company may execute any works reasonably necessary for such alteration and the reasonable expense of executing such works shall be borne by the Corporation.

(2) If any difference arises under this section between the Corporation and any railway company that difference shall be referred to arbitration under this Order.

31. For protection of Severn Commissioners.

As to junctions.

32. (1) The Corporation may and if required to do so by the owners of any light railway or tramway constructed up to the boundary of the City at the termination of Railway (No. 1) shall make a junction between the railway and such light railway or tramway.

(2) The Corporation shall give due notice to the owners of any such light railway or tramway of any works required to be carried out for the purpose of effecting that junction or of making maintaining altering or renewing any points or crossings in connection therewith and with the notice shall submit to the said owners plans sections and specifications of the proposed works and the Corporation shall not commence the works until the said plans sections and specifications have

been approved by the said owners or in case of difference by an arbitrator appointed as hereinafter provided: Provided that if the said owners do not within fourteen days notify to the Corporation any objection thereto they shall be taken to have approved them;

(3) When the said plans sections and specifications have been approved as aforesaid the Corporation may proceed to execute and shall thereafter maintain such works in accordance therewith to the reasonable satisfaction of the said owners;

(4) The rails and works of all such junctions points and crossings so far as they are on or in the light railway or tramway of the said owners shall be the absolute property of the said owners so that nothing in the nature of a joint-ownership shall be established in connection therewith;

(5) The provisions of this section shall be subject to any agreement between the Corporation and the said owners under this Order.

(6) If any difference arises under this section between the Corporation and the said owners that difference shall be referred to arbitration under this Order.

Provision as to gas and water companies &c.

33. For the purposes of making forming laying down maintaining repairing or renewing the railway the Corporation may where and as far as it is necessary or may appear expedient for the purpose of preventing frequent interruption of the traffic by repairs or works in connection with the same alter the position of any mains pipes or apparatus for the supply of gas or water or any tubes wires or apparatus for telegraphic or other purposes subject to the provisions of this Order and also subject to the following restrictions; (that is to say)—

(1) Before laying down or altering as aforesaid the railway in a road or place in which any such mains pipes tubes wires or apparatus (hereinafter in this section referred to as "mains or apparatus") may be laid the Corporation shall whether they contemplate altering the position of any mains or apparatus or not give seven days' notice to any person other than the Corporation to whom such mains or apparatus may belong or by whom they are controlled (hereinafter in this section referred to as "the owners") of their intention to lay down or alter the railway and shall at the same time deliver a plan and section of the proposed work. If it should appear to the owners that the laying down or alteration of the railway as proposed would endanger any such mains or apparatus or interfere with or impede the supply of water or gas or the telegraphic or other communication the owners may give notice to the Corporation to lower or otherwise alter the position of the said mains or apparatus in such manner as may be considered necessary and all alterations to be made under this section shall be made with as little detriment and inconvenience to the owners or to the inhabitants of the district as the circumstances will admit and under the superintendence of the owners if they think fit to attend after receiving not less than forty-eight hours' notice for that purpose which notice the Corporation are hereby required to give;

(2) The Corporation shall not remove or displace any mains or apparatus or other works belonging to or controlled by the owners or do anything to impede the passage of water or gas or the telegraphic or other communication into or through such mains or apparatus without the consent of the owners or in any other manner than the owners shall approve until good and sufficient mains or apparatus and other works necessary or proper for continuing the supply of water or gas or telegraphic or other communication as sufficiently as the same was supplied by the mains or apparatus proposed to be removed or displaced shall at the expense of the Corporation have been first made and laid down in place thereof and ready for use and to the satisfaction of the owners;

(3) The Corporation shall not lay down any such pipes contrary to the regulations ot any Act of Parliament relating to the owners or relating to telegraphs and shall lay down any water main or water pipe if so required by the owners at a depth not less than that at which it was previously laid and unless otherwise agreed between the Corporation and the owners in every case so as to leave a covering of at least thirty inches from the surface of the road above such main or pipe;

(4) The Corporation shall make good all damage done by them to property belonging to or controlled by the owners and shall make full compensation to all parties for any loss or damage which they may sustain by reason of any interference with such property or with the private service pipes of any person supplied by the owners with water or gas;

(5) If by any such operation as aforesaid the Corporation interrupt the supply of water or gas in or through any main or main pipe they shall be liable to a penalty not exceeding twenty pounds for every day upon which such supply shall be so interrupted.

(6) Any works to be executed pursuant to this section in relation to the lowering or altering the position of any such mains or apparatus shall if the owners so desire be executed by them at the reasonable expense of the Corporation and in that case the owners shall within seven days of receiving notice from the Corporation as aforesaid give notice of their intention so to execute such work and shall commence execute and complete the same with all reasonable despatch;

(7) Any difference arising under this section between the Corporation and the owners shall be referred to arbitration under this Order;

(8) Nothing in this section shall apply in the case of any electric lines or works of any undertakers the position of which may be altered under Section 15 of the Electric Lighting Act 1882.

For protection of sewers, &c.

34. (1) Where the railway will interfere with any sewer drain watercourse subway defence or work or will affect the sewerage or drainage of any district the Corporation shall give to the proper authority if other than the Corporation fourteen days' notice in writing of their intention to commence the railway with all necessary particulars relating thereto and they shall not commence the same without the approval of such authority unless such authority fail to signify their approval or disapproval or give other directions within the said period of fourteen days.

(2) The Corporation shall comply with all reasonable directions of the said authority and shall provide in such manner as such authority shall reasonably require for the protection of the said sewers and works and shall repay to the said authority any reasonable expenses to which they may be put by reason of the railway.

(3) All such protective works shall be done by the Corporation under the superintendence (if such superintendence shall be given) of the said authority or may be executed by the said authority if they so desire at the reasonable expense of the Corporation. If such authority intend to execute such works themselves they shall and where they have received such notice as aforesaid from the Corporation within fourteen days after such receipt give to the Corporation notice accompanied by sufficient particulars of that intention and shall commence execute and complete the works with all reasonable despatch.

(4) If any difference arises under this section between the Corporation and any authority that difference shall be referred to arbitration under this Order.

Rights of authorities and companies &c. to open roads.

35. (1) Nothing in this Order shall take away or abridge any power to open or break up any road or the footpath of any road on which the railway is laid or any other power vested in any local authority or road authority for any of the purposes for which such authority is respectively constituted or in any person for the purpose of laying down repairing altering or removing any pipe or apparatus for the supply of gas or water or any tubes wires or apparatus for telegraphic or other purposes but in the exercise of such power every such authority or person (other than the Corporation) shall be subject to the following restrictions; (that is to say)—

(A) They shall cause as little detriment or inconvenience to the Corporation as circumstances will admit;

(B) Before they commence any work whereby the traffic on the railway will be interrupted they shall (except in case of urgency when no notice shall be necessary) give to the Corporation notice of their intention to commence such work specifying the time at which they will begin to do so such notice to be given eighteen hours at least before the commencement of the work;

(C) They shall not be liable to pay to the Corporation any compensation for injury done to the railway by the execution of such work or for loss of traffic occasioned thereby or for the reasonable exercise of the powers so vested in them as aforesaid;

(D) Whenever for the purpose of enabling them to execute such work such local authority or road authority shall so require the Corporation shall either stop traffic on the part of the railway to which the notice shall refer where it would otherwise interfere with such work or shore up and secure the same at their own risk and cost during the execution of the work there: Provided that such work shall be completed with all reasonable despatch;

(E) No such authority or person shall execute such work so far as it immediately affects the railway except under the superintendence of the Corporation unless the Corporation refuse or neglect to give such superintendence at the time specified in the notice for the commencement of the work or discontinue the same during the progress of the work and they shall execute such work at their own expense and to the reasonable satisfaction of the Corporation: Provided that any additional expense imposed on them by reason of the existence of the railway in any road or place where any such mains pipes tubes wires or apparatus shall have been laid before the construction of the railway shall be borne by the Corporation.

(2) If any difference arises under this section between the Corporation and any such authority or person that difference shall be referred to arbitration under this Order.

As to manholes.

36. Where the railway is constructed or intended to be constructed or reconstructed over any manhole or entrance into any sewer of any authority or so close to such manhole or entrance as to make the use thereof dangerous the Corporation shall at their own expense if in the district of any local authority or upon any road under any road authority other than the Corporation upon being required by such authority so to do alter the position of such manhole or entrance in such manner as may be reasonably necessary and if in such district or upon such road as may also be approved by such authority or such authority may at their own option at the reasonable expense of the Corporation make such alteration in the position of such manhole or entrance. If such authority intend to execute such work themselves they shall commence execute and complete the same with all reasonable despatch and in any case where the railway is already constructed they shall give to the Corporation not less than forty-eight hours' notice before they commence the works. If any difference arises between the Corporation and the authority under this section that difference shall be referred to arbitration under this Order.

Agreements with adjoining owners &c.

37. The Corporation may enter into and carry into effect agreements and arrangements with any parties who are the owners lessees or occupiers of any lands adjoining or near to the railway and are competent to enter into such agreements or arrangements with reference to the construction and maintenance by the Corporation or by such parties of sidings junctions works and conveniences

for their accommodation or benefit either on the lands owned by leased to or occupied by them or on lands of the Corporation acquired for or appropriated to the purposes of the undertaking and the Corporation may apply their funds for the purposes of such agreements or arrangements in the same manner as if they were the purposes of this Order.

Penalty unless railway is opened within the time limited.

38. If the Corporation fail within any period limited by or extended by the Board of Trade under this Order to complete the railway the Corporation shall be liable to a penalty of twenty pounds a day for every day after the expiration of the period so limited until the railway is completed and opened for the public conveyance of passengers or until the sum received in respect of such penalty amounts to five per centum on the estimated cost of the works and the said penalty may be applied for by any landowner or other person claiming to be compensated under this Order or interested in accordance with the provisions of the next following section of this Order and in the same manner as the penalty provided in Section 3 of the Railway and Canal Traffic Act 1854 and every sum of money recovered by way of such penalty as aforesaid shall be paid under the warrant or order of such court or judge as is specified in that section to an account opened or to be opened in the name of the Paymaster-General for and on behalf of the Supreme Court in the bank and to the credit specified in such warrant or order and shall not be paid thereout except as hereinafter provided but no penalty shall accrue in respect of any time during which it shall appear by a certificate to be obtained from the Board of Trade that the Corporation were prevented from completing or opening the railway by unforeseen accident or circumstances beyond their control.

Application of penalty.

39. Every sum of money so recovered by way of penalty as aforesaid shall be applicable and after due notice in the "London Gazette" shall be applied towards compensating any landowners or other persons whose property has been interfered with or otherwise rendered less valuable by the commencement construction or abandonment of the railway and also in compensating all road authorities other than the Corporation for the expense incurred by them in taking up the railway or any materials connected therewith placed by the Corporation in or on any road and in making good all damage caused to such roads by the construction or abandonment of the railway and shall be distributed in satisfaction of such compensation as aforesaid in such manner and in such proportions as to the High Court may seem fit. If no such compensation is payable or if a portion of the sum or sums of money so recovered by way of penalty as aforesaid has been found sufficient to satisfy all just claims in respect of such compensation then the said sum or sums of money recovered by way of penalty or such portion thereof as may not be required as aforesaid shall if a receiver has been appointed or the railway in respect of which the penalty has been incurred or any part thereof has been abandoned be paid or transferred to such receiver or applied in the discretion of the Court as part of the assets of the Corporation and subject to such application shall be repaid or retransferred to the Corporation.

Inspection by Board of Trade.

40. The railway shall not nor shall any part thereof be opened for public traffic until the same has been inspected and certified to be fit for such traffic by the Board of Trade.

The remaining sections of the Order relate to matters connected with working, supply of electricity, bye-laws, rates and charges, &c., and, generally speaking, are similar to the corresponding clauses of an Order under the Tramways Act 1870.

APPENDIX VIII.

Regulations made by the Board of Trade under the provisions of Special Tramways Acts or Light Railway Orders authorising lines on public roads; for regulating the use of electrical power; for preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes, structures, or substances; and for minimising as far as is reasonably practicable injurious interference with the electric wires, lines, and apparatus of parties other than the Company, and the currents therein, whether such lines do or do not use the earth as a return.

First Made, March, 1894: Revised, April, 1903.

Definitions.

In the following regulations—

The expression "energy" means electrical energy.

The expression "generator" means the dynamo or dynamos or other electrical apparatus used for the generation of energy.

The expression "motor" means any electric motor carried on a car and used for the conversion of energy.

The expression "pipe" means any gas or water pipe or other metallic pipe, structure, or substance.

The expression "wire" means any wire or apparatus used for telegraphic, telephonic, electrical signalling, or other similar purposes.

The expression "current" means an electric current exceeding one thousandth part of one ampere.

The expression "the Company" has the same meaning as in the Tramways Act [Light Railways Order].

Regulations.

1. Any dynamo used as a generator shall be of such pattern and construction as to be capable of producing a continuous current without appreciable pulsation.

2. One of the two conductors used for transmitting energy from the generator to the motors shall be in every case insulated from earth, and is herein-after referred to as the "line"; the other may be insulated throughout, or may be uninsulated in such parts and to such extent as is provided in the following regulations, and is herein-after referred to as the "return."

3. Where any rails on which cars run or any conductors laid between or within three feet of such rails form any part of a return, such part may be uninsulated. All other returns or parts of a return shall be insulated, unless of such sectional area as will reduce the difference of potential between the ends of the uninsulated portion of the return below the limit laid down in Regulation 7.

4. When any uninsulated conductor laid between or within three feet of the rails forms any part of a return, it shall be electrically connected to the rails at distances apart not exceeding 100 feet by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or by other means of equal conductivity.

5. (*a*.) When any part of a return is uninsulated it shall be connected with the negative terminal of the generator, and in such case the negative terminal of the generator shall also be directly connected, through the current-indicator herein-after mentioned, to two separate earth connections which shall be placed not less than 20 yards apart.

(*b*.) The earth connections referred to in this regulation shall be constructed, laid, and maintained so as to secure electrical contact with the general mass of earth, and so that an electro-motive force, not exceeding four volts, shall suffice to produce a current of at least two amperes from one earth connection to the other through the earth, and a test shall be made at least once in every month to ascertain whether this requirement is complied with.

(*c*.) Provided that in place of such two earth connections the Company may make one connection to a main for water supply of not less than three inches internal diameter, with the consent of the owner thereof and of the person supplying the water, and provided that where, from the nature of the soil or for other reasons, the Company can show to the satisfaction of an inspecting officer of the Board of Trade that the earth connections herein specified cannot be constructed and maintained without undue expense the provisions of this regulation shall not apply.

(*d*.) No portion of either earth connection shall be placed within six feet of any pipe except a main for water supply of not less than three inches internal diameter which is metallically connected to the earth connections with the consents herein-before specified.

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* The Board of Trade will be prepared to consider the issue of regulations for the use of alternating currents for electrical traction on application.

(*e*.) When the generator is at a considerable distance from the tramway the uninsulated return shall be connected to the negative terminal of the generator by means of an insulated return conductor, and the generator shall have no other connection with earth; and in such case the end of the insulated return connected with the uninsulated return shall be connected also through a current indicator to two separate earth connections, or with the necessary consents to a main for water supply, or with the like consents to both in the manner prescribed in this regulation.

(*f*.) If the current indicator cannot conveniently be placed at the connection of the uninsulated return with the insulated return, this instrument may consist of an indicator at the generating station connected by insulated wires to the terminals of a resistance interposed between the return and the earth connection or connections. The said resistance shall be such that the maximum current laid down in Regulation 6 (i.) shall produce a difference of potential not exceeding one volt between the terminals. The indicator shall be so constructed as to indicate correctly the current passing through the resistance when connected to the terminals by the insulated wire before-mentioned.

6. When the return is partly or entirely uninsulated the Company shall in the construction and maintenance of the tramway (*a*) so separate the uninsulated return from the general mass of earth, and from any pipe in the vicinity; (*b*) so connect together the several lengths of the rails; (*c*) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; and (*d*) so maintain the efficiency of the earth connections specified in the preceding regulations as to fulfil the following conditions, viz.:—

(i.) That the current passing from the earth connections through the indicator to the generator or through the resistance to the insulated return shall not at any time exceed either two amperes per mile of single tramway line or five per cent. of the total current output of the station.

(ii.) That if at any time and at any place a test be made by connecting a galvanometer or other current-indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanché cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanché cell if the direction of the current is from the pipe to the return.

In order to provide a continuous indication that the condition (i.) is complied with, the Company shall place in a conspicuous position a suitable, properly connected, and correctly marked current-indicator, and shall keep it connected during the whole time that the line is charged.

The owner of any such pipe may require the Company to permit him at reasonable times and intervals to ascertain by test that the conditions specified in (ii.) are complied with as regards his pipe.

7. When the return is partly or entirely uninsulated a continuous record shall be kept by the Company of the difference of potential during the working of the tramway between points on the uninsulated return. If at any time such difference of potential between any two points exceeds the limit of seven volts, the Company shall take immediate steps to reduce it below that limit.

8. Every electrical connection with any pipe shall be so arranged as to admit of easy examination, and shall be tested by the Company at least once in every three months.

9. Every line and every insulated return or part of a return except any feeder shall be constructed in sections not exceeding one-half of a mile in length, and means shall be provided for isolating each such section for purposes of testing.

10. The insulation of the line and of the return when insulated, and of all feeders and other conductors, shall be so maintained that the leakage current shall not exceed one hundredth of an ampere per mile of tramway. The leakage current shall be ascertained daily before or after the hours of running when the line is fully charged. If at any time it should be found that the leakage current exceeds one-half of an ampere per mile of tramway the leak shall be localised and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localised and removed within 24 hours. Provided that where both line and return are placed within a conduit this regulation shall not apply.

11. The insulation resistance of all continuously insulated cables used for lines, for insulated returns, for feeders, or for other purposes, and laid below the surface of the ground, shall not be permitted to fall below the equivalent of 10 megohms for a length of one mile. A test of the insulation resistance of all such cables shall be made at least once in each month.

12. Where in any case in any part of the tramway the line is erected overhead and the return is laid on or under the ground, and where any wires have been erected or laid before the construction of the tramway in the same or nearly the same direction as such part of the tramway, the Company shall, if required so to do by the owners of such wires or any of them, permit such owners to insert and maintain in the Company's line one or more induction-coils or other apparatus approved by the Company for the purpose of preventing disturbance by electric induction. In any case in which the Company withhold their approval of any such apparatus the owners may appeal to the Board of Trade, who may, if they think fit, dispense with such approval.

13. Any insulated return shall be placed parallel to and at a distance not exceeding three feet from the line when the line and return are both erected overhead, or eighteen inches when they are both laid underground,

14. In the disposition, connections, and working of feeders, the Company shall take all reasonable precautions to avoid injurious interference with any existing wires.

15. The Company shall construct and maintain their system as to secure good contact between the motors and the line and return respectively.

16. The Company shall adopt the best means available to prevent the occurrence of undue sparking at the rubbing or rolling contacts in any place and in the construction and use of their generator and motors.

17. In working the cars the current shall be varied as required by means of a rheostat containing at least 20 sections, or by some other equally efficient method of gradually varying resistance.

18. Where the line or return or both are laid in a conduit the following conditions shall be complied with in the construction and maintenance of such conduit:

(*a*.) The conduit shall be so constructed as to admit of examination of and access to the conductors contained therein and their insulators and supports.

(*b*.) It shall be so constructed as to be readily cleared of accumulation of dust or other *débris*, and no such accumulation shall be permitted to remain.

(*c*.) It shall be laid to such falls and so connected to sumps or other means of drainage, as to automatically clear itself of water without danger of the water reaching the level of the conductors.

(*d*) If the conduit is formed of metal, all separate lengths shall be so jointed as to secure efficient metallic continuity for the passage of electric currents. Where the rails are used to form any part of the return they shall be electrically connected to the conduit by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or other means of equal conductivity, at distances apart not exceeding 100 feet. Where the return is wholly insulated and contained within the conduit, the latter shall be connected to earth at the generating station or sub-station through a high resistance galvanometer suitable for the indication of any contact or partial contact of either the line or the return with the conduit.

(*e*.) If the conduit is formed of any non-metallic material not being of high insulating quality and impervious to moisture throughout, the conductors shall be carried on insulators the supports for which shall be in metallic contact with one another throughout.

(*f*.) The negative conductor shall be connected with earth at the station by a voltmeter and may also be connected with earth at the generating station or sub-station by an adjustable resistance and current-indicator. Neither conductor shall otherwise be permanently connected with earth.

(*g*.) The conductors shall be constructed in sections not exceeding one-half a mile in length, and in the event of a leak occurring on either conductor that conductor shall at once be connected with the negative pole of the dynamo, and shall remain so connected until the leak can be removed.

(*h*.) The leakage current shall be ascertained daily, before or after the hours of running, when the line is fully charged, and if at any time it shall be found to exceed one ampere per mile of tramway the leak shall be localised and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localised and removed within 24 hours.

19. The Company shall, so far as may be applicable to their system of working, keep records as specified below. These records shall, if and when required, be forwarded for the information of the Board of Trade.

Daily Records.

No. of cars running.
No. of miles of single tramway line.
Maximum working current.
Maximum working pressure.
Maximum current from the earth plate or water-pipe connections (*vide* Regulation 6 (i.)).
Leakage current (*vide* Regulations 10 and 18 (*f*.)).
Fall of potential in return (*vide* Regulation 7).

Monthly Records.

Condition of earth connections (*vide* Regulation 5).
Minimum insulation resistance of insulated cables in megohms per mile (*vide* Regulation 11).

Quarterly Records.

Conductance of joints to pipes (*vide* Regulation 8).

Occasional Records.

Specimens of tests made under provisions of Regulation 6 (ii.).

Board of Trade,
7, Whitehall Gardens, S.W.

April, 1903.

APPENDIX IX.

GUARD WIRES ON ELECTRIC TRAMWAYS.

New Regulation.

If and whenever telegraph or telephone wires, unprotected with a permanent insulating covering, cross above, or are liable to fall upon, or to be blown on to, the electric conductors of the tramways, efficient guard wires shall be erected and maintained at all such places.

EXPLANATORY MEMORANDUM.

Note.—The expression " telegraph wire " includes all telegraph and telephone wires.

For the purpose of this memorandum, telegraph wires are divided into two classes, namely:
(*a*) Wires weighing less than 100 lbs. per mile.
(*b*) Wires weighing 100 lbs. or more per mile.

Each guard wire should be well earthed at one point at least, and at intervals of not more than five spans. The resistance to earth should be sufficiently low to insure that a telegraph or telephone wire falling on and making contact with the guard wire and the trolley wire at any time will cause the circuit breaker protecting that section to open.

The earth connection should be made by connecting the wire through the support to the rails by means of a copper bond. When first erected, the resistance to earth of the guard wires should be tested, and periodical tests should be made to prove that the earth connection is efficient.

Guard wires should be, in general, of galvanised steel, but in manufacturing districts in which such wires are liable to corrosion bronze or hard drawn copper wires should be used.

The gauge of the guard wire should not be less than seven strands of No. 16 or one of No. 8 wire.

The supports for the guard wires should be rigid and of sufficient strength for their purpose, and at each support each guard wire should be securely bound in or terminated.

The rise of the trolley boom should be so limited that if the trolley leaves the wire it will not foul the guard wires.

Telegraph Wires crossing Trolley Wires.

Class (a).—Wires weighing less than 100 lbs. per Mile.

The guard wires may be of the cradle or hammock type, attached to the arms of telegraph poles. It is necessary that the spans should be short; and if required an additional pole or poles should be set.

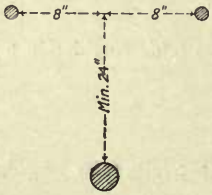

Fig. 1.

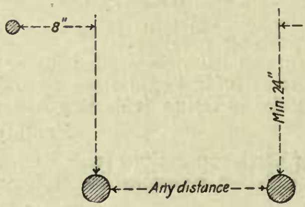

Fig. 2.

(1.) Where there is one trolley wire, two guard wires should be erected (Fig. 1).

(2.) Where there are two trolley wires at a distance not exceeding 12 feet apart, two guard wires should be erected (Fig. 2).

(3.) In special cases, at junctions or curves, where parallel guard wiring would be complicated, two guard wires may be so erected that a falling wire must fall on them before it can fall on the trolley wire.

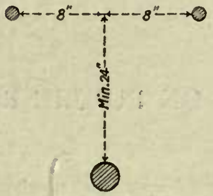

Fig. 3.

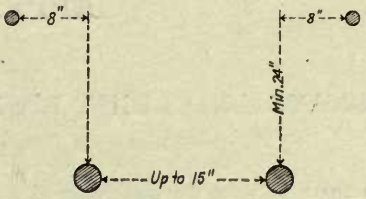

Fig. 4.

Class (b).—Wires weighing 100 *lbs or more per Mile.*

(4.) Where there is only one trolley wire, two guard wires should be erected (Fig. 3).

(5.) Where there are two trolley wires not more than 15 inches apart, two guard wires should be erected (Fig. 4).

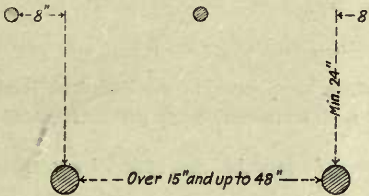

Fig. 5.

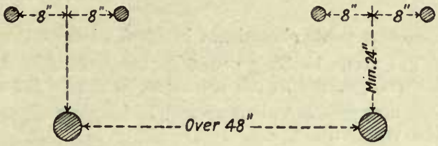

Fig. 6.

(6.) Where there are two trolley wires and the distance between them exceeds 15 inches, but does not exceed 48 inches, three guard wires should be erected (Fig. 5).

(7.) Where the distance between the two trolley wires exceeds 48 inches, each trolley wire should be separately guarded (Fig. 6).

(8.) It is desirable, where possible, to divert telegraph wires from above trolley junctions and trolley wire crossings, and undertakers should endeavour to make arrangements to that effect with the owners of telegraph wires.

TELEGRAPH WIRES PARALLEL TO TROLLEY WIRES.

Classes (a) and (b).

(9.) Where telegraph wires not crossing a trolley wire are liable to fall upon or to be blown on to a trolley wire, a guard wire should be so erected that a falling wire must fall on the guard wire before it can fall on the trolley wire.

(10.) When guard wires are attached to other supports than the trolley poles they should be connected with the rails at one point at least.

(11.) When it is possible that a telegraph wire may fall on an arm or a stay, or a span wire, and so slide down on to a trolley wire, guard hooks should be provided.

General.

Minimum guarding requirements for Classes (*a*) and (*b*) are provided for in this memorandum, but in exceptional cases, such as in very exposed positions, or for unusually heavy telegraph wires, special precautions should be taken.

Board of Trade, 7, Whitehall Gardens, London, S.W. September, 1902.

APPENDIX X.

TRAMWAYS AND LIGHT RAILWAYS LAID ON PUBLIC ROADS.

Clearance.

The space between the inner rails of a double line must depend upon the overhang of the cars. It is, however, necessary that there should be at least 15 inches between the sides of passing cars, and also a similar space between the side of a car and any standing work such as lamp, telegraph and trolley wire posts in a street.

There should be at least 15 inches between the side of a car and the kerb, whether on straight or curved roads.

The clearance between the top deck of cars and the under-side of bridges should not be less than 6 ft. 6 ins.

Posts and Brackets.

Centre posts should not be used without the consent, in every case, of the Board of Trade.

The stone kerbing round centre posts should not be such as to enable any person to stand upon as a refuge, unless the clearance is ample for safety.

Where bracket arms 16 feet in length will not suffice, it is desirable that span wire construction should be used.

Permanent Way.

The weight of rails should not be less than 90 lbs. per yard, 100 lbs. being preferred.

The groove of the rail should not exceed *one and an eighth inch* in width, but a groove not exceeding *one and a quarter inch* will be accepted on curves of less than one chain radius.

The details of permanent way and mode of construction as approved by the Board of Trade should not be varied at any time without the Board's consent.

Board of Trade, January, 1905.

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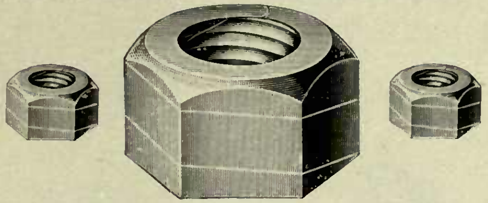

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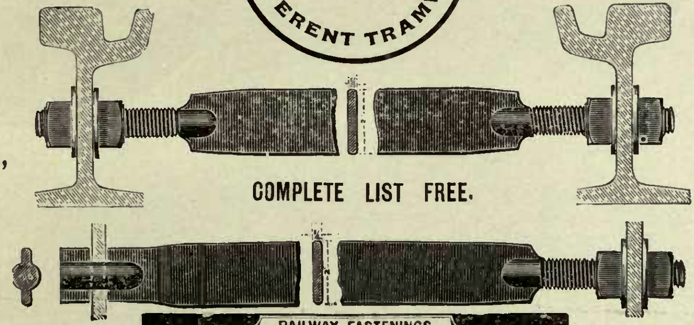

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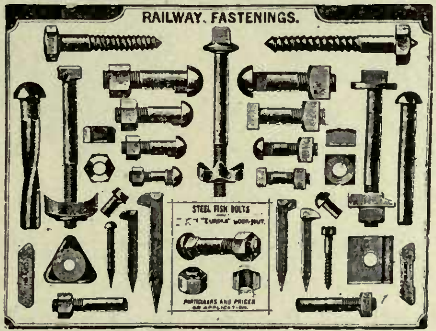
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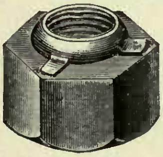

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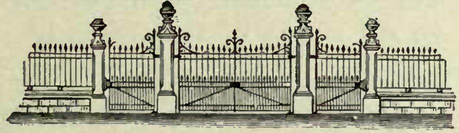

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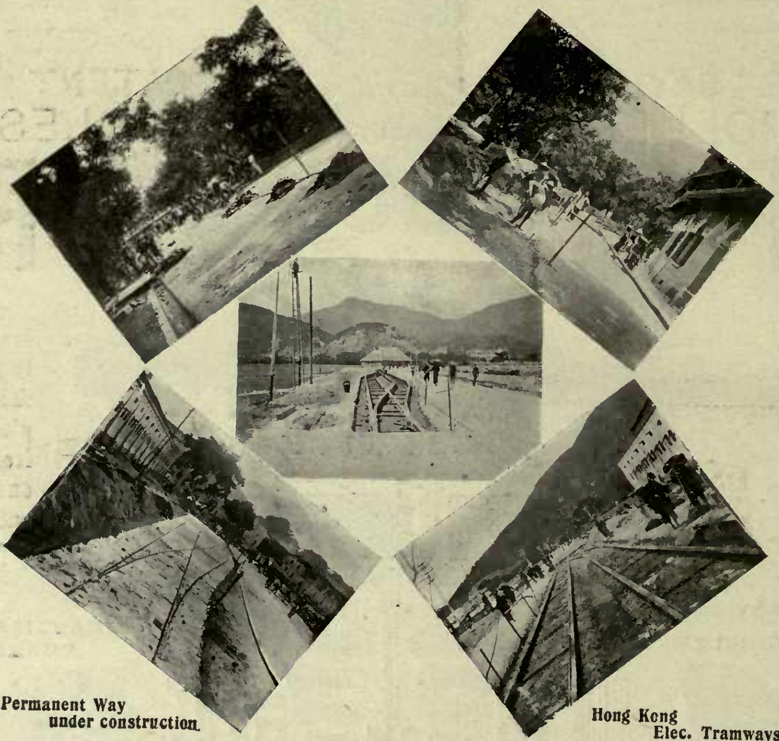

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